ELEMENTARY NOTES ON ENGINEERING

FOR

SURVEY CLASSES IN BENGAL

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PART I

Materials.

THE chief materials used in the construction of buildings, culverts and roads are bricks, tiles, *surki*, stone, lime, cement, mortar, plaster, concrete, reinforced concrete, metals and alloys, timber, paint and varnish, glue, putty, coal tar, asphalt and earthenware pipes.

CHAPTER I.

Bricks, Tiles and Stones.

Pucca bricks are made of prepared clay formed in a mould of suitable shape and size, and then burnt at a sufficiently high temperature to drive off the moisture and to harden the inside without vitrifying the outside. Bricks which are merely dried in the sun instead of being burnt are called *kutcha* bricks. The quality of a brick depends on the composition of the clay from which it is made, and the way in which it is moulded and burnt.

Brick earth.—It is beyond the province of these notes to go into the chemistry of the subject. In fact the chemical analysis of a clay gives very little information as to its suitability for brick making.

The best test is that of actually trying the clay by making a few bricks with it.

Weathering, tempering and moulding.—Before moulding, the clay is prepared by digging it into heaps and allowing these to " weather " for a fortnight. (In Bengal, October is the best month to do this.) The clay is then " tempered " by being cut, mixed with water, and trodden upon until it becomes soft, covered with mats and allowed to dry till of the right consistency for moulding.

The tempering is improved by cutting and mixing thoroughly in a pug mill. A sketch of one suitable for working by two pairs of bullocks is shown in Plate 1.

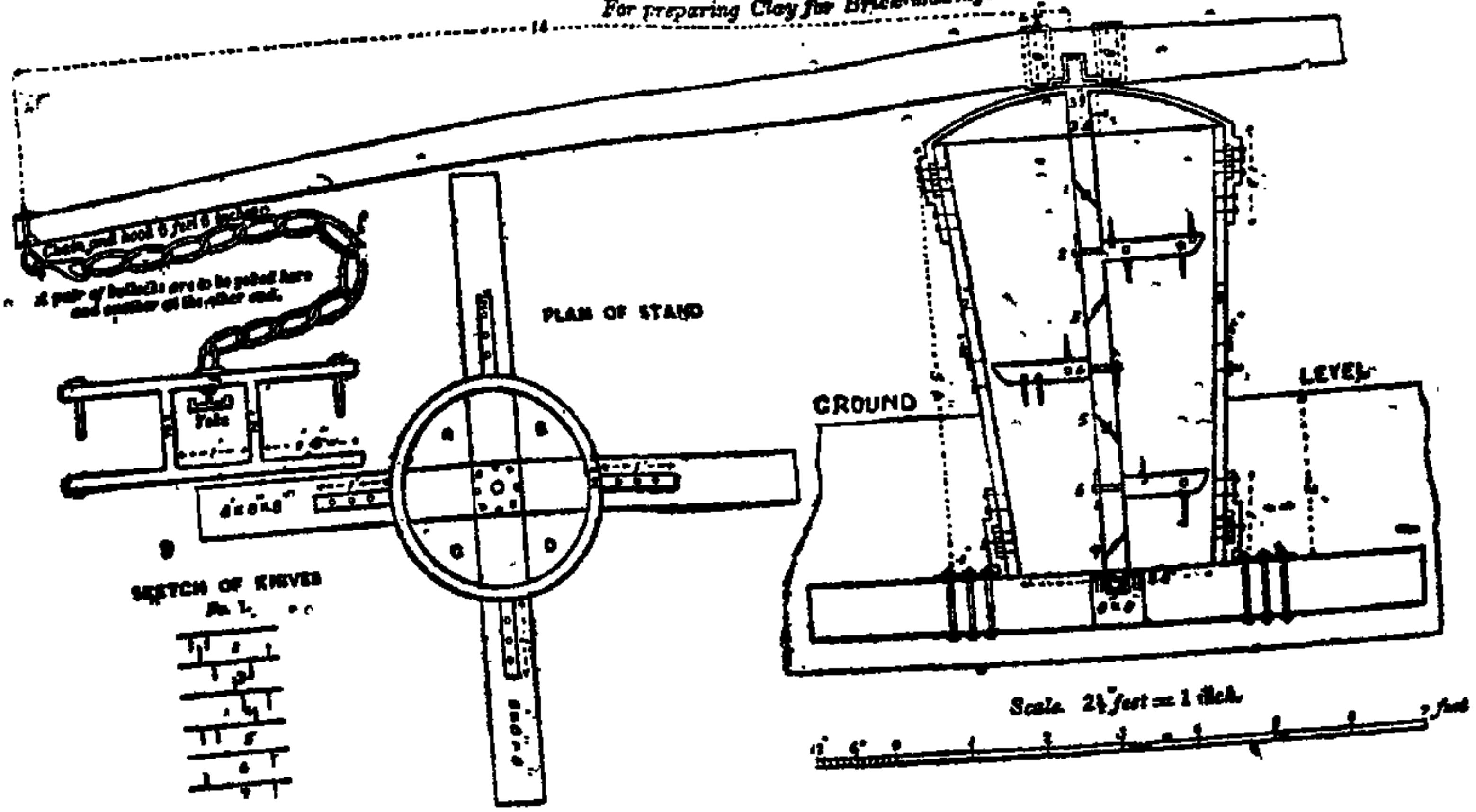
The clay is put in at the top, and water added as required to moisten it, the mill being kept constantly at work. The six top knives are 4 inches wide and are bolted into the spindle at an angle of 45°, having teeth let into them ; the blades of the teeth are 4 inches long. The teeth are fastened to the knives at unequal intervals. The seventh (bottom) knife has no teeth, is 6 inches wide, and is fixed to the spindle at an angle of 55°. The mill is sunk two feet into the ground to allow the clay to be conveniently thrown in from above and to avoid having a raised track for the bullocks. There is an opening at the side and near the bottom of the mill from which the prepared clay oozes out. A ramp must be made down to this opening to allow of the clay being carried away to the moulders.

The opening at the bottom of the mill is only stopped when the clay is first put in and until the latter is sufficiently prepared for the

SECTION OF A PUG-MILL

For preparing Clay for Brick-making.

PLATE. I.



moulders, when the tamping is withdrawn and not again replaced while the mill remains in constant daily use.

Moulding.—The mould for shaping the bricks should be made from one-twelfth to one-twentieth larger than the size of brick to be made, to allow for the shrinkage during burning. The mould should be made of thoroughly seasoned hard wood. The sides and edges, which wear very fast, should be protected with brass plates. Moulds are also made of wrought iron. These are cheaper, seldom need repairs, and have the further advantage of turning out bricks of more uniform size.

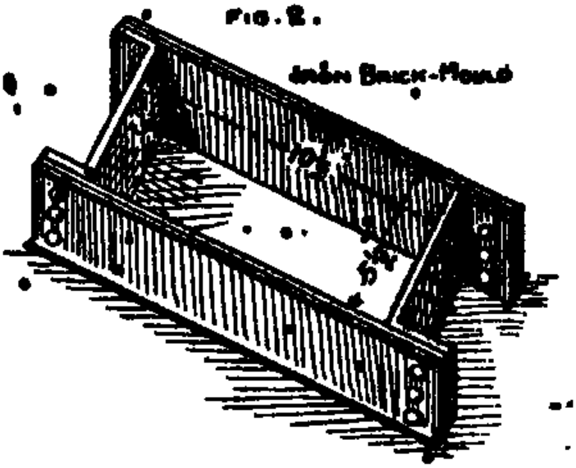


FIG. 2.

Iron Brick-Mould

The dimensions of the mould shown in the sketch (figure 2) are suitable for standard bricks used by the Public Works Department, Bengal (9¾" × 4½" × 2¾").

The moulder dashes the clay forcibly into the mould, pressing it carefully so as to completely fill the mould.

The superfluous clay is removed by the "strike" (a straight edge of metal) which is passed along the top of the mould and pressed well down on its edges. The moulder now places a thin pallet board (12" × 6" × 1½") on the top of the mould, leaving the brick on the pallet board. Another labourer then lifts the brick by placing another pallet board on the brick and carries it thus to the drying ground.

The *kutcha* bricks are dried in rows on raised ground, which should be sanded. The stacks are best formed by having the breadth equal to two bricks laid longitudinal with intervals between the bricks, the alternate tiers being *along* and *across* the stack, all on edge.

Burning.—In India both kiln and clamps are used in burning bricks.

The knowledge obtained by reading descriptions of clamps and kilns is not to be compared with that obtained as a result of visits to the actual clamps and kilns, while these are under construction, and later in working order. The intelligent use of your eyes, tongue, and note book cannot be over emphasised, and every opportunity should be taken of noting all details of engineering works that may come under your observation.

After such a visit you will have learnt that the clamp method is slow and the percentage of first-class bricks turned out is small, but that in a Bull's trench kiln, with 20 chambers, 5 lakhs of bricks are turned out per month, with an average monthly consumption of 2,500 maunds of coal dust. Sixty-six per cent of the outturn will be first-class bricks.

Characteristics of a good brick.—A first-class brick should be free from cracks, flaws, stones or lumps of any kind, regular in shape, and uniform in size. *Arrises* (edges) should be square, straight and well defined; surfaces even, but not too smooth or the mortar will not adhere to them. The proportion of water absorbed should be about one-eighth of the weight of the brick. The brick should give out a ringing sound when struck. The surface should not be easily scored by a knife even in the centre, and the finger nail should make no impression or scratch at all.

Specific gravity about 1·8. Weight of a standard brick used in Bengal (9½" × 4½" × 2¾") = 7·6 lbs. Average crushing load, 60 tons per square foot.

Surki.—*Surki* is the name given to pounded brick, the properties of which will be considered when treating of mortar, but it is in the immediate neighbourhood of the brick kiln that its manufactory should be located, because the broken bricks as they come from the kiln, instead of being carried to the works, which they often wastefully are, or otherwise lost sight of, can be made into *surki* and placed under sheds to receive it. Pieces of brick, of which there are always plenty, should be used up into *surki* and the freshly burnt clay is easier to crush.

A pair of crushing stones attached to each set of kilns will always keep up the necessary supply and will be an economical arrangement. The stones should be 5 feet in diameter and 12" to 15" thick. Belt-driven *surki* mills suitable for grinding *surki* on a large scale, say 500 cubic feet per day of 9 hours, are economical in the long run.

Fire-clay.—Fire-clay is any clay capable of standing a high temperature without melting or becoming soft. Such clays are said to be "refractory."

Fire bricks are made from this clay by processes similar to those adopted in making ordinary bricks.

The clay is dug, weathered, tempered, ground under rollers, passed through riddles to remove lumps, pugged, moulded, burnt in kilns at a slowly increasing, but to a very high, temperature, and then allowed to cool gradually.

They are used for setting ovens, lining furnaces, fire places, etc.

Tiles.—Common tiles are made of the same material as ordinary bricks but greater care in selecting and preparing the clay is necessary and the drying and burning must be very gradual.

Paving tiles shaped as squares, hexagons, etc., vary in size 6" × 6" to 12" × 12" and are about 1" thick.

Roofing tiles are of several kinds.—*Plain tiles* are flat and either rectangular, or of various patterns (*See* plates 3 and 4).

Pan tiles are moulded flat and afterwards bent to the form shown in plate 3.

Corrugated tiles are similar to pan tiles, but each tile has three or four corrugations.

Mangalore tiles manufactured by the Basel Mission, are made of the best Malabar clay, well dried and thoroughly burnt in patent kilns. Making allowance for laps, about 150 tiles are required for each 100 square feet for roofing; 1,000 tiles weigh about 2¼ tons and 250 tiles make a cart load. These tiles weigh about 5¾ lbs. dry and 6 7/12 lbs. when soaked. Excellent tiles of various patterns are made at Ranigunge potteries. (Plate 4).

TILES. PLATE. 3.

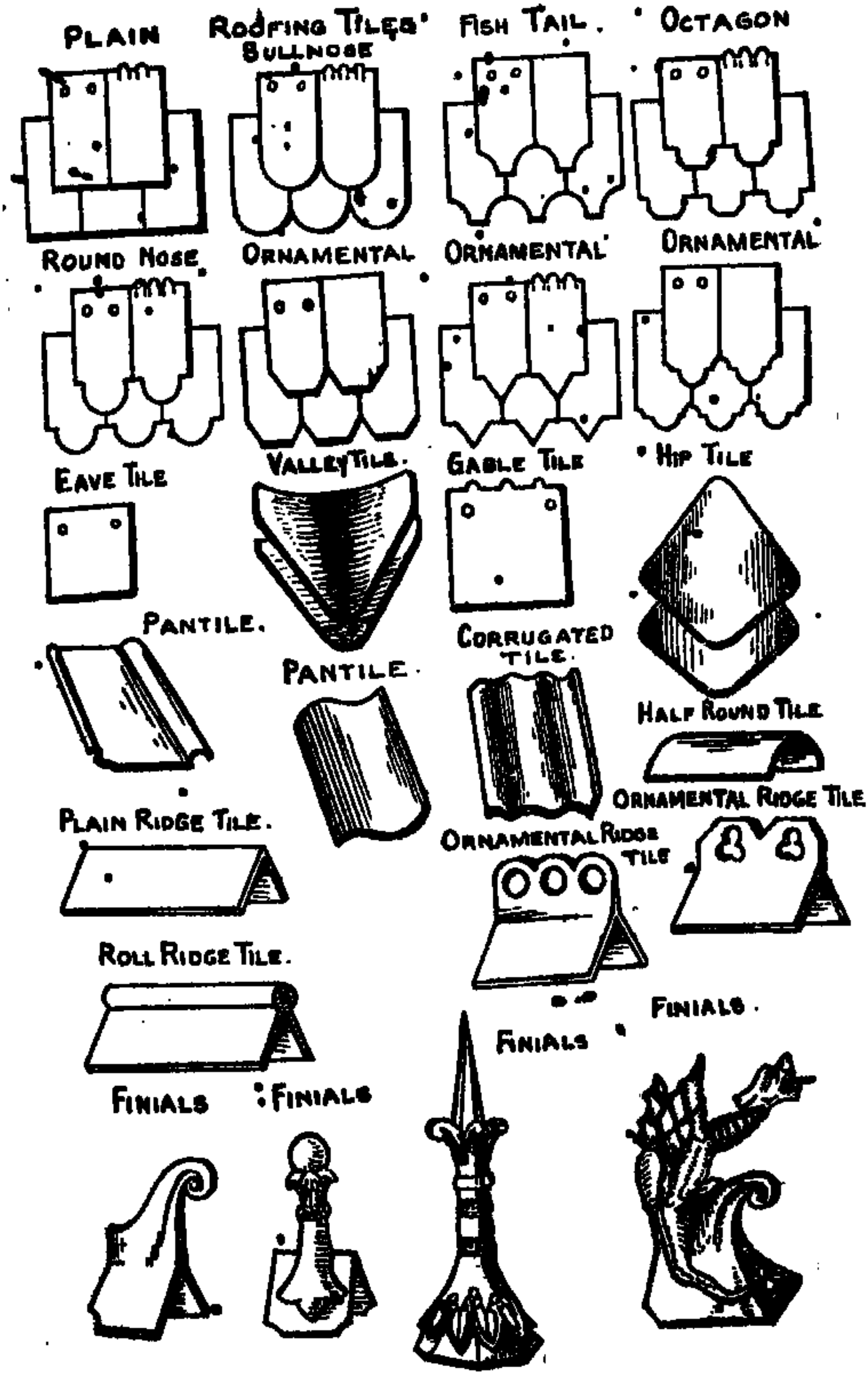
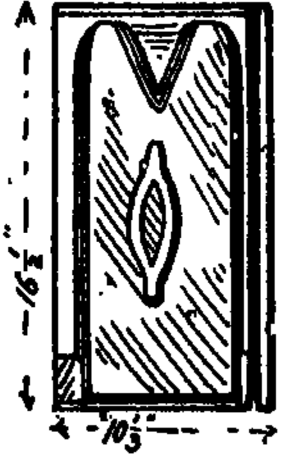


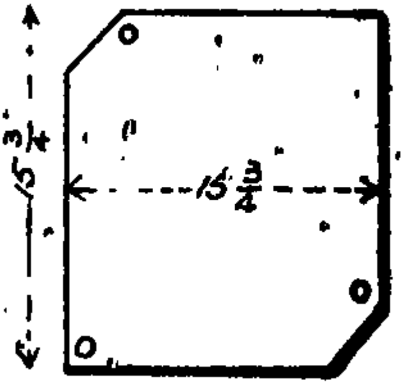
PLATE. 4.

RANIGANJ TILES

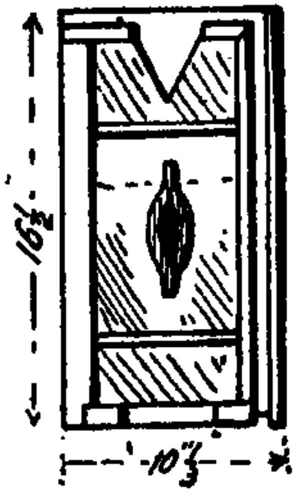
UPPER SIDE

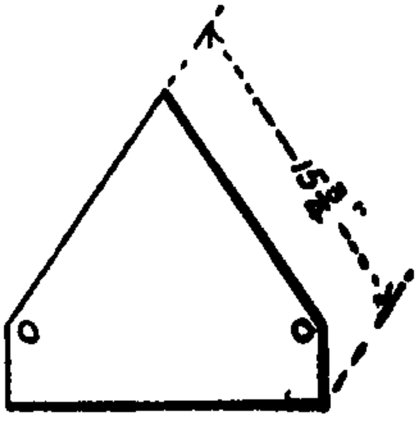


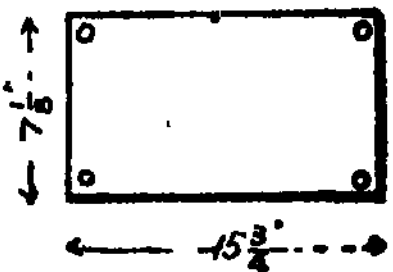
'ETERNIT' ASBESTOS CEMENT TILES.



LOWER SIDE.







Asbestos cement tiles are largely imported for roofing and other purposes. Different manufacturers have different names for their products, e.g., "*Eternit*" "*Poilite*", etc. These tiles are tough and comparatively light (about 22 lbs. per square yard as compared with 140 lbs. per square yard for mastic tiles). They can be supplied in terra-cotta, grey or blue colours. They are cheaply and easily fixed; 85 are required for 180 square feet of plain roof. The standard sizes are shown in plate 4; the thickness is $\frac{5}{32}$".

Miscellaneous Clay Wares.

Pipes.—Pipes are made from clay, very finely ground, washed, sieved, tempered, pugged, and forced by machinery through a mould, dried and baked in a kiln.

They are made of various sections but the circular are the most common. They are generally 2 feet long of internal diameters varying from 2 to 12 inches. The thickness varies with the diameter and the class of ware, *i.e.*, whether for stoneware, fire-clay, etc.

The smallest thickness being $\frac{5}{8}$".
The thickness of 12" stoneware pipes is $1\frac{1}{4}$".
" " of 12" fire-clay " $1\frac{1}{16}$".
" " of 12 other clay " 1".

Sewer pipes should be viteous throughout, hard, impervious to water, uniform in thickness, glazed inside, and outside flawless and ring clearly when struck.

Socket pipes if required to carry sewage, should have the socket in the same piece with the pipe and not formed separately. The market size, of socket pipes vary from 2" to 30" diameter and length 3'. There are many patents for ensuring a close-joint between pipes. Standford's patent consists of casting rings of a mixture of coal tar, sulphur and ground pipes upon the spigot and in the socket of each pipe. When the pipes are placed together they fit so as to form a watertight joint without the addition of cement.

Bends are curved lengths of pipe, the centre lines forming portions of a circle of varying radii. The diameter in the bore of the bend varies from 2" to 18".

Taper Pipes are required to join two pipes of different diameter.

Junctions are usually 2' in length and are required when one pipe enters the side of another.

Stone.

As there are practically no building stones available in Bengal it is not proposed to make more than a passing reference to this material; these notes having been prepared for Survey Classes in Bengal only.

Characteristics.—The chief characteristics of stone are :—

Durability, facility for working, hardness, strength, appearance, natural bed.

Durability depends upon the chemical composition, physical structure, and the position in which the stone is placed—a stone which weathers well in pure air may be rapidly destroyed by the atmosphere of a manufacturing town. The only safe test of the durability of a stone under given conditions is its actual exposure for many years under such conditions. Something may be learnt by examining the exposed wall of the quarry which has not been disturbed for some years, or by examining an old building in which the stone has been used.

Facility of working.—The mason should be able to convert the stone into the shapes required with as little difficulty as possible. A soft stone of even grain should be selected for carved work; a hard stone would be suitable for economical rubble masonry.

Hardness is essential when the stone is to be subjected to much friction as in pavements, or when required for quoins (corner stone). Hardness is also essential for road metalling.

Strength.—So long as stone is used in the ordinary way, *i.e.*, subjected to compression only, its strength need only be considered in cases of exceptionally great or varying pressure over a small area, *e.g.* columns carrying great weight, for arches, for engine beds and the like. The strength of an ordinary building stone is far more than sufficient in all ordinary cases.

Appearance.—The choice of stone for the sake of appearance is often important in the case of external work in important and conspicuous buildings, these stones should be free from flaws, clay holes, spots of colour, etc. They should be uniform in colour and structure.

Natural Bed.—The natural bed is that surface on which the material was originally deposited in the quarry. All stones which have a laminated (layers) structure should be placed in the walls of a building on the "natural bed." In cornices with undercut mouldings the laminæ should be placed vertically. In arches the laminæ should be placed parallel to the centre line of the voussoirs, and at right angles to the face of the arch.

Classifications.—The Engineer usually classifies building stones as follows:—

(1) Granites. (2) Slates. (3) Sandstones. (4) Limestone.

Granite is used for piers, docks, breakwaters, road metal and in all places where weight and durability are required. It is not suitable for fine carving. It takes a fine polish and is therefore suitable for such ornamental work as polished columns and plinths of memorial statues, etc. Excellent granite is obtainable in the Nizam's Dominions, Guzarat, and the Southern Mahratta Country. Basalt is found at Kurla and Satri in the Bombay Presidency.

Slate is used for roofing and pavements. Good slate should not absorb water and should have a very fine grain. Those obtainable in Southern India are mostly coarse and soft. Hard black slate is found at Kurnool.

Slate is also obtainable in Rajputana, Kangra Valley, Chamba and near Delhi.

Sandstones are grains of sand cemented together into a solid rock, and are formed by deposit in layers of varying thickness and have a distinct bed plane. The thickness of the beds varies from a few inches to over 150 feet. The colour of sandstone is very variable white, yellow, brown, red, blue, grey. Gritstone is valuable for heavy engineering works; flagstone for pavements. Many varieties of sandstone are obtained in Gwalior. Tehri sandstone is suitable for paving. Bamor sandstone for building purposes generally; also obtainable at Mirzapore, Agra, Orissa, Delhi and Trichinopoly.

Limestone.—Stones which consists mainly of carbonate of lime are called limestones. There is however a very great variety in the members of the class due to the great difference in chemical composition, hardness, weathering properties and texture. For example, marble, chalk and Portland stone each consists of nearly pure carbonate of lime, but their weathering qualities are very dissimilar.

Dense, uniform, homogeneous stones with fine grains of a crystalline texture are the best for weathering.

Marble takes a high polish and is used in buildings for chimney pieces, columns, and other places where a decorative effect is desired. Marble is found at Madura, Nellore, Jeypore, etc. (Jeypore marble is used in the Victoria Memorial, Calcutta.)

CHAPTER II.

Lime, Cement, Mortar, Concrete, Plaster, Asphalte.

Lime and Cement.

Lime and cement are most important materials used in engineering works. Lime is obtained by the calcination of limestones and is used in engineering works (1) as a matrix for concrete, (2) in preparing mortar, and (3) as a cementing material in plaster.

In India the chief limestones from which lime is obtained are calcareous "tufa", limestone boulders and kankar, obtainable in large quantities in the districts bordering the hills on the Gangetic plains. *Calcination* means heating to redness in air.

Quicklime is the lime obtained immediately after calcination.

Slaking is the chemical combination of quicklime with water.

Slaked lime is the result of slaking.

Setting is the hardening of lime.

Hydraulicity is that property of a paste or mortar containing lime by which it sets more or less or rapidly under water. The properties of a lime or cement depend very much upon the constituent of the limestone from which they are prepared. These properties lead to the following classification :—

(*a*) Pure or rich or fat limes.
(*b*) Poor lime.
(*c*) Hydraulic limes ... { Feebly Hydraulic. / Moderately " / Eminently "
(*d*) Cements ... { Natural. / Artificial.

Pure Limes are those which contain not more than 6 per cent. of impurities insoluble in acids. They are chiefly used for plastering and whitewashing. They may be used for mortar when mixed with surki, but only when hydraulic lime is unobtainable. They are obtained from white chalk, marble, limestone and shells.

Poor Limes contain from 15 to 30 per cent. of impurities insoluble in acids. They take longer to slake but do not increase in bulk to such an extent as pure limes. A smaller proportion of sand is required when preparing mortar because of the impurities they already contain. Mortar made from poor lime is however less economical than that from fat lime and requires a more troublesome manipulation. It should therefore only be used when no better can be had.

Hydraulic Limes contain such substances as silica and alumina besides lime. When the stone is burnt these two substances combine to form calcium silicate and calcium aluminate. The proportions of these substances present in the lime give the measure of the hydraulicity, and render the lime independent of external agents for their setting properties.

Feebly hydraulic limes contain 6 to 16 per cent. of these useful substances.

Moderately hydraulic limes contain 16 to 26 per cent. and

Eminently hydraulic limes 26 to 36 per cent.

Hydraulic limes are the most suitable for engineering work.

The matrix for concrete should only consist of such limes.

In India all "kankar" limes are more or less hydraulic. All lime that has been damaged by rain, moisture or dirt should be rejected.

Cements are distinguished from limes by not slaking when mixed with water after calcination. They are calcareous substances and are similar in many respects to the best hydraulic limes but possess far greater hydraulic properties. They are divided into two classes, *natural* and *artificial*.

Natural cements are those obtained by the calcination of stones containing from 20 to 40 per cent. of clay, the other constituent of the stone being carbonate of lime, either alone, or mixed with carbonate of magnesia. Calcined cement stones are but little effected by water, but when ground to powder and wetted they produce a paste which sets under water in from 5 minutes to 5 hours and harden within a year so as to have the strength, which varies in different specimens from that of soft brick to that of strong stone. This setting and hardening takes place without any appreciable preliminary slaking action. So called "roman cement" is the best known. It should be mixed in small quantities and used immediately. It sets in about 15 minutes. It is valuable for temporarily pointing work which has to be done between tides, and for all purposes where quick setting is essential. It is about one-third the strength of Portland cement (to be described later) and is almost entirely supplanted by the latter for all engineering works.

Artificial cements.—The most valuable of all cements is that known as *Portland cement*, so called from its resemblance to Portland stone. It is not proposed to describe the tests to which Portland cement should be subjected. The attention of the student is drawn to the specification of Portland cement issued by the British Engineering Standard Committee. This standard specification is now generally adopted. Senior students should carry out the tests as described by that committee during their course. Only approved brands should therefore be used. It should be fresh, uncaked, grey or greenish grey in colour, specific gravity not less than 3·10 when delivered to the consumer, be sufficiently fine to pass through a sieve 76×76, 5776 meshes per square inch and leave not more than 3 per cent., in the sieve, bear a tensile stress of 200 lbs. per square inch after being mixed with water and kept moist for 12 hours, thereafter being kept under water for seven days. It should not crack or turn yellow while setting. The strength of good Portland cement increases with age up to a certain time.

Burning, Slaking, Mixing, Setting.—Four distinct processes are gone through from the time limestone is quarried to the time when the lime sets in the work. These are burning, slaking, mixing and setting.

Burning.—Limestone may be burned in a clamp or kiln just as with bricks. The clamps or kilns may be worked on the continuous or the intermittent system. In the continuous system the lime is gradually removed from the bottom of the kiln and fresh lime and fuel added on top. This is economical, but the lime is unequally burnt. The intermittent system consists in firing and burning a kiln full of limestone each time, and the burnt lime removed after the kiln has cooled. A more evenly burnt lime results. The operation is repeated. Each operation takes about seven days. A good type of kiln for continuous working is that used in the Military Works Services. A plan and section is given in Plate 5. This is called a kiln because there is an enclosing wall, but the method of burning is really that of a clamp.

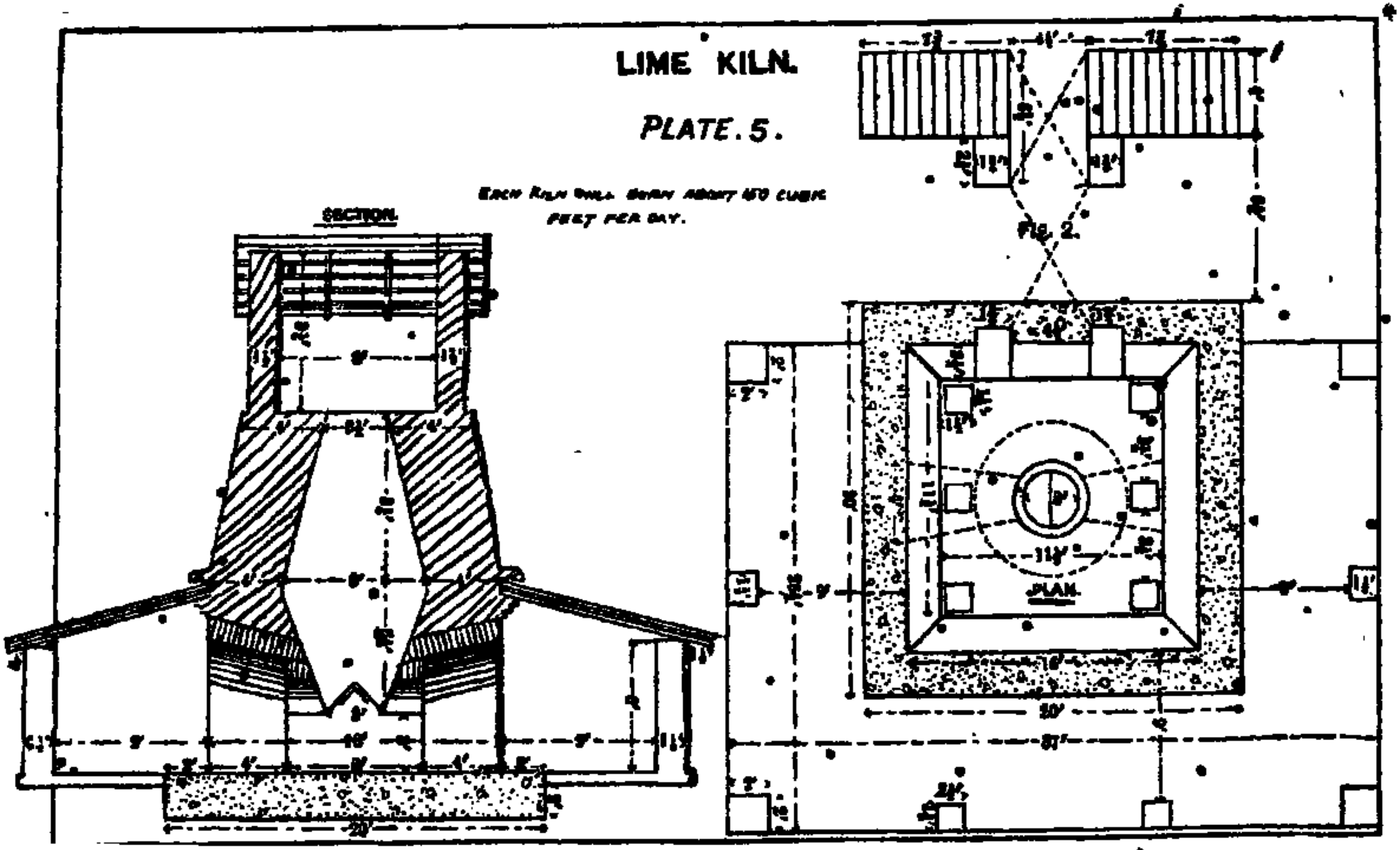
Slaking.—When water is sprinkled on freshly burned lime, calcium hydrate is formed which has the property of combining with carbon dioxide to form crystals of calcium carbonate. It is the formation of these crystals which give strength to the mortar. This chemical combination is accompanied by a hissing crackling sound, slight explosions and the evolution of heat and steam. The volume of the lime increases to twice or three times its original bulk. This process is called slaking. The freshly slaked lime is soluble. If therefore more water be added some of this slaked lime is dissolved and a saturated solution formed. If quicklime is exposed to the air, it will combine with carbon dioxide (which always exists in the atmosphere) to form calcium carbonate, but under such conditions the calcium carbonate is not crystalline. This process is called "air slaking." If a paste is made from slaked lime and placed in water it will dissolve slowly, and if the water is constantly changed, entirely disappear. If the paste is allowed to remain in air (not under water) the surface of the paste combines with the carbon dioxide of the atmosphere and thus reconverts the surface of the paste into calcium carbonate to a depth of less than half an inch. The interior of the sample remains pulpy and undergoes no change. It is important that every particle of quicklime should be thoroughly slaked before preparing mortar, otherwise the unslaked portions will expand after the mortar is placed in the work and this expansion will disturb the work. Sand or surki is mixed with lime to make mortar for these reasons :—

(*a*) To counteract the excessive shrinkage when mortar is made with pure lime.

(*b*) To form channels through which the necessary carbon dioxide can have access to those particles behind the surface and combine to form crystals of calcium carbonate, and

(*c*) Sand and surki being cheaper than lime, the volume of mortar is economically increased.

Setting is not to be confused with mere drying. During drying the water in the mixture evaporates. The setting of lime depends upon the absorption of carbon dioxide from the air by the particles of slaked lime in solution in the mortar. This absorption results in the formation of crystals of calcium carbonate throughout the mass. These crystals tend to cling to rough substances such as the particles of sand or surki and the surfaces of bricks. Because of this the addition of sand or surki (within limits) increases the strength of the mortar. If lime alone were used the surface would set first and form an impervious layer, preventing access of the carbon dioxide on the particles within this layer. The moisture inside would eventually evaporate leaving nothing but a crumbly friable powder.



LIME KILN.

PLATE. 5.

Each Kiln will burn about 150 cubic feet per day.

(b)

Pure Lime Mortars never set throughout its mass in thick walls owing to their dependence on external agents for setting.

Hydraulic Limes do not depend for their setting upon external agencies. The setting of such limes and cements is chiefly due to the formation of crystals of hydrated calcium silicate and hydrated calcium aluminate and in the case of hydraulic limes to a small extent to the absorption of carbon dioxide. Such limes and cements therefore are able to set even in the centre of very thick walls and under water. Hydraulic limes do not increase so much in bulk when slaked, and the slaking process takes a much longer time than it does in the case of pure limes.

Mortar.

Mortar is of two kinds :—

Ordinary Mortar composed of lime and sand (or surki) mixed into a paste with water.

Cement Mortar in which cement is substituted for lime. Both kinds are used in brick (or stone) work to build the bricks or stones together and to provide a soft resting place, thereby preventing the inequalities of the bricks from bearing upon one another and therefore causing an equal distribution of pressure over the beds. The vertical spaces are also filled up by the mortar and this suffices to form strong joints able to withstand the weather. It is also used as a matrix in concrete for plastering and other purposes. Since the properties of mortar depend upon the quality and proportions of the materials used in its preparation, and also on the method of mixing, it is important that these should be considered in further detail. Neither rich or poor limes should be used if hydraulic limes are available for reasons already given. Hydraulic lime or cement should always be used in mortar for engineering work of any importance. For work under water such lime or cement is absolutely necessary. If there be any choice, the class of hydraulic lime or cement to be used will depend upon the nature and situation of the work to be done. For ordinary buildings not very much exposed, slightly hydraulic lime will suffice to form a moderately strong weather-resisting joint. For masonry under water an eminently hydraulic lime or cement mortar is necessary. If the work be required to set quickly Roman cement would be used, but if great ultimate strength is required Portland cement should be adopted. The sand to be used in mortar should be perfectly clean, otherwise the lime will not adhere to it. It should not be too fine a grain as this would prevent access of air, which is necessary for setting. Calcareous sands are better than siliceous ones. The salts present in sea sand attract moisture and causes the mortar to be permanently damp. River sand is better. If surki is used instead of sand, it should be made from fully burnt (not overburnt) bricks, or by grinding or pounding broken tiles and pottery. The surki must be perfectly clean and must be passed through a sieve containing 64 meshes to the inch before being mixed with the lime. Ashes and coal dust are also used as substitutes for sand to make the "black-mortar" used for pointing, slating, and some kinds of rubble masonry. The water used for mixing mortar should not contain mud, clay or other impurities. Salt water causes damp and efflorescence. Dirty water is objectionable for the same reasons as dirty sand.

Proportions of materials used.—The usual proportion of lime and sand is 1 to 2. This may be varied according to the quality of lime used and the relative position in the work. In Bengal several varieties of lime are used; the more important being Sylhet lime (from the Khasia Hill, Sylhet), Kutni lime (from the limestone hills, Kutni), Sutna lime (from the limestone found in Sutna). If Sylhet lime is used, the proportions of lime to surki is generally specified to be 1 to 2. If "ghooting" lime (obtained from kankar) is used, the proportion of lime to sand or surki is usually 5 to 7. The quantity of water used will be that required to reduce the mixture to the consistency of thick honey. The proportions of kankar lime and sand in mortar used for foundations is 1 to 1½, or 1 to 1 if surki is substituted for sand. For superstructure work the proportion is 1 lime to 2 or 3 surkhi.

Mixing.—Having decided on the proportions of the ingredients they are prepared and mixed as follows:—

A convenient quantity of quicklime is measured out on to a wooden or stone floor under cover, and water added to slake it. The sand or surki is then spread over the slaked lime, thus keeping in the heat and moisture and increasing the speed of slaking. This heap is turned over and shovelled into a mortar mill, enough water being added to obtain the right consistency (see above). It is of great importance that the mixing should be thoroughly done, no two grains of the dry sand (or surki) should lie together without having a layer of lime or cement between them. It is for this reason that mortar mills are used for mixing. For small works the mixing is done by hand and as this involves a great deal of time to ensure a thorough mixing, it is essential that the work be carefully supervised. Mortar made with cement should be mixed dry, the ingredients being turned over several times previous to adding water, thus ensuring a thorough incorporation of the ingredients. It is of great importance, especially in India, that the bricks or stones to be imbedded in the mortar should be thoroughly soaked, so that they cannot absorb the moisture from the mortar and also in order to remove the dust from their surfaces, which would otherwise prevent the mortar from adhering. Mortar should be used as stiff as it can be spread; the joints should always be well filled. Mortar for plastering should be ground a second time after an interval so as to ensure thorough slaking of the lime; the mortar should then be used at once. Mortar should be placed on a small platform or in a tub when required for use—not on the ground where it would get dirty. Mortar which has set, or lain for more than 24 hours after it has been ground, should not be used in any work. It should be kept ready for use in narrow troughs which may be covered with matting in the hot weather to prevent its drying or setting too quickly.

Concrete.

Concrete is composed of cement or lime, sand, broken stone or brick and water. The selection of each of these materials depends largely upon local conditions. Certain general conditions, as noted below, may serve as a guide to the student.

The Matrix is the cement or lime mortar in which the broken stone or brick is imbedded. It is a wise rule to use Portland cement for nearly all classes of concrete, being more uniform and reliable, while its strength is so much greater than natural cement. The brand of Portland cement should be selected from those having a first class reputation, and in important work it should be tested as laid down in the standard specification of Portland cement by the British Engineering Standards Committee. The sand should be clean; test this by rubbing it with the fingers of one hand over the palm of the other. If the sand is dirty, it will discolour the palm. Preference should be given to sand containing a mixture of coarse and fine grains.

The aggregate is the broken stone or clean gravel, or any hard material that can be procured economically, *e.g.*, broken brick, shingle, slag, etc., etc. If gravel is chosen it is advisable to screen it over a ⅜th inch mesh screen. If it is dirty, it should be washed before being shovelled on to the mixing platform. If broken stone is selected as the aggregate, it should be screened to remove the dust. Broken brick or limestone is better than shingle, since they offer rough surfaces to which the matrix adheres more readily than it would to the smooth surfaces of shingle or flints. If weight is not essential, a light porous aggregate, such as "breeze" may be used *e.g.*, lintels or in fire-resisting positions. The aggregate is screened so that the size of each piece may not be more than 2½ inches or less than 1 inch. A 1½-inch or 2-inch mesh is the average size of the screen. The aggregate may be broken by hand, except when large quantities are required. In the latter case power-driven stone crushers are used.

Proportions of ingredients.—For a small work it will be sufficiently accurate to select the proportion of cement to sand which will give the required strength to the concrete, and then use twice as much aggregate as sand. For example, the following four proportions will serve as a rough guide to the selection of materials for different kinds of work. The name given to each mixture is quoted from "Concrete" by Taylor and Thompson.

A rich mixture for columns and other structural parts subjected to high stresses, or requiring exceptional water tightness, 1 : 1½ : 3 by volume of Portland cement, sand and broken stone, respectively.

A standard mixture for reinforced floors, beams, arches, reinforced machine foundation subject to vibration, tanks, sewers, conduits, 1 : 2 : 4 by volume of Portland cement, sand and broken stone, respectively.

A medium mixture for retaining walls, abutments, piers, ordinary walls, floors, sidewalks :—1 : 2½ : 5 by volume.

A lean mixture for unimportant work, 1 : 3 : 6.

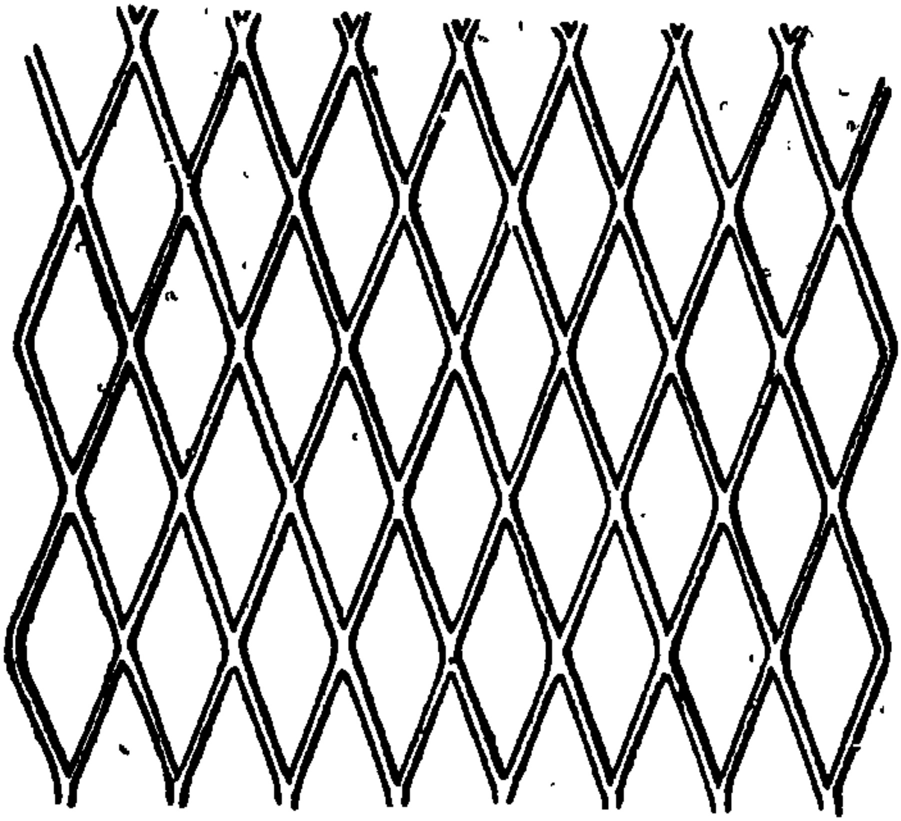
It will be noted that the aggregate in each of the above mixture is twice the quantity of sand. It is not generally known that the quantity of broken stone + the quantity of sand is *not* equal to the volume of the finished concrete. If the broken stone is of uniform size, the concrete will cost from 5 to 10 per cent. more on account of the additional quantity of material required to make a given volume of concrete. In measuring the broken stone before mixing there will be less solid matter in a measure, and consequently more sand and cement will be necessary to fill the spaces between the stones.

Consequently, if we start with definite proportions of material, more concrete will be made if the matrix is composed of stones of varying sizes than if the stone had been screened to a uniform size.

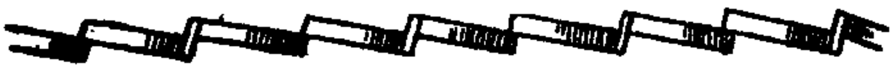
Mixing and laying concrete.—The employment of machinery for mixing the ingredients will depend upon the quantity to be laid and upon the cost per c. ft. of concrete laid. The amount of work turned out will depend considerably upon the arrangements of the gang. The materials for the concrete ought of course to be collected on a platform as near the work as possible; the cement should be protected from rain and moisture. Assuming that the proportions have been decided upon and the materials collected, the mixing should proceed as follows:—The proportions decided upon are measured out by means of boxes made of sizes to suit the relative proportions of the ingredients to be used. These measured quantities are heaped up together, and turned over two or three times, so as to be thoroughly mixed. Water should now be sprinkled through a "rose" in sufficient quantity as to allow the whole to be thoroughly mixed. Too much water is likely to wash the lime or cement away. This moist mixture should again be turned over two or three times. If hydraulic lime is used, it should be in a fine powder and carefully slaked. No unslaked portions should be allowed to mix with the other ingredients. If Portland cement is used, it should be cooled before mixing. Roman cement, if used, should be fresh. After thorough mixing the concrete should be rapidly taken to the place, where it is to be laid, gently tipped into position, and carefully rammed in horizontal layers of not more than 6" thick. The surface of each layer should be swept clean, made rough by means of a pick, washed and covered with thin coating of cement. This surface is now fit for receiving the next layer. The joints between the layers need careful attention. If proper precautions are not taken, they are found to be a source of weakness rendering the mass of concrete liable to split easily with wedges. If there is no time to allow a layer to set before adding the next, it is better to ram the layer as quickly as possible and add the next layer before the former has set. Once a layer has commenced to set, do not disturb it by ramming or walking over it. If the concrete is to be laid under water, it should be protected from the water during its passage down to the site of deposit, either by shoots or boxes or sometimes by filling the bags with concrete and depositing both bags and its contents.

Reinforced Concrete is concrete in which mild steel is imbedded in such a way that it resists the tensional or shearing stress, leaving the concrete to resist the compressive stresses only. Its strength is therefore considerably increased, and when the concrete and steel are efficiently disposed, it resists disintegration much longer than the material it usually displaces. It has also greater fire-resisting properties. It is economical, and its monolithic character is often advantageous in cases of soft soils. *The steel* is the reinforcement; it should have a tensile strength of 28 to 32 tons per sq. inch. The elongation in a length of 8" should be 20 per cent. Several sections are employed, but the circular section is probably the most popular. In India expanded metal reinforcement is best known. It is suitable for plain and curved surfaces, packs closely, is easily transported, is simple and economical. Expanded metal is made from sheets of rolled steel, cut and expanded by machinery into meshes of diamond shape as shown in Fig. 8A . It is manufactured in sheets of almost any convenient size up to 16', the long way of the meshes. Some sections are indented or twisted to prevent slipping through the concrete, but *good cement concrete* adheres so well to steel that twisted and indented sections are unnecessary. The surface of the steel should be free from grease, loose scale, and the like; a slight surface rust is not objectionable.

FIG: 8A



EXPANDED METAL.



Section through intersections.

The Concrete used in reinforced work needs most careful attention. The best aggregates are broken sandstone or shingle (limestone should never be used on account of its change under the action of heat), the aggregate must be clean and screened from all sand. The mortar or binding material must be in sufficient quantity to fill all voids between adjacent pieces of aggregate. The sand should be perfectly clean, sharp and coarse, and of all sizes from $\frac{1}{8}$ inch downwards. The cement should be Portland and satisfy the British Standard specifications already referred to.

Further remarks on reinforced concrete appear in Part II of these notes.

Plaster.

Plaster is the plastic material applied to the surfaces of parts of a building, which after being disposed in the required manner, hardens and retains its form. The plaster is generally applied to rough surfaces to give a smooth face, which in its turn serves as a ground for some finish such as whitewash, paint paper or distemper. It is also used externally when it is desired to obtain an appearance which is preferred to the natural surface of the materials used in the construction and in some cases certain kinds of plaster are used to protect structural members from damage by fire.

Ingredients.—Plaster like concrete and mortar consists of a matrix and an aggregate. The former being the active material which sets, or hardens, and binds, while the aggregate is the inert granular material which is bound by the matrix.

The matrix is either lime or cement and the aggregate sand In general the notes on lime, cement and sand, under the heading "mortar" have equal application regarding their qualities, selection, properties, etc., for plaster. The proportions of these ingredients depend upon the kind of plaster required.

Whitewash is made from shell lime mixed with water. I shell lime is not available fresh stone lime slaked on the spot should be used. The slaked lime is placed in tubs nearly full of water and mixed up until it attains the consistency of thin cream. After mixing, the wash should be taken out in small quantities and strained through a coarse cloth into "ghurrahs" (earthen pots). Two chittacks of gum to each cubic foot of lime is added to the strained whitewash and the whole boiled. Whitewash should be laid on in three coats with a brush, the coats being laid on vertically and horizontall , alternately. Each coat should be allowed to dry before the next is applied.

Asphaltes.

Asphaltes are combinations of bituminous and calcareous compounds and are divided into "natural" and "artificial".

Natural asphaltes are important for use in engineering works and are superior to the artificial imitations. It is a bituminous limestone of a rich brown colour found in large quantities in France and Switzerland, the component parts of which consist of calcium carbonate impregnated with about 10 per cent. of mineral tar (bitumen).

Artificial asphaltes are formed of a mixture of coal tar, pitch, chalk, quicklime, sand and sawdust, ground iron and slag, heated and laid in a semi-fluid state. The pitch used in the preparation of artificial asphaltes should be true or mineral bitumen, and not the coal tar pitch which is obtained on distilling coal tar. The latter is brittle and softens more readily under heat, is easily crushed and altogether inferior. The distinguishing properties of asphalte are as follows :—Damp-resisting, durable, noiseless, sanitary, non-inflammable, vermin proof, easily cleaned, slightly elastic, unaffected by urine, easily applied.

In consequence of these properties it has a variety of uses as will appear in Part II of these notes.

CHAPTER III.

Metals and Alloys.

The metals most generally used by the engineer are iron, copper, lead, zinc, tin, and combinations of these (alloys), *e.g.*, brass, gun metal, Muntz metal, phospor bronze, white metal, bellmetal, Babbits metal, pewter, solder.

Iron.

Ores.—Iron is not found to any great extent in the pure metallic state, and has to be extracted from its oxides, carbonates or sulphides, called *ores* ; all ores are mixed more or less with impurities such as manganese, magnesia, silica, alumina, lime, carbon, sulphur and phosphorous.

Dressing.—To separate the earthy impurities the ores are crushed in mills and washed. This process is called dressing.

Calcination and Roasting.—After dressing, the ores are roasted to drive off moisture and carbonic acid.

Smelting.—The ore is now mixed with a "flux" which extracts from it most of the impurities ("Gangue") when both ore and flux are subjected to intense heat in a blast furnace. The metal sinks down in a fluid state, while the impurities combine with the flux, and run off in a light and fusible "slag".

Once a furnace is lighted it is not allowed to go out until it requires repairing; fuel and ore are continually replenished when sufficient molten iron has collected, the furnaces "tapped" and the iron run into a long channel formed in sand and having branches on each side called the sow and her pigs, hence the term "pig iron" given to the rough bars of unpurified iron run from the blast furnace. It is in this form that the iron-manufacturer purchases his iron and uses it either for casting, or the manufacture of wrought iron and steel.

Pig Iron.

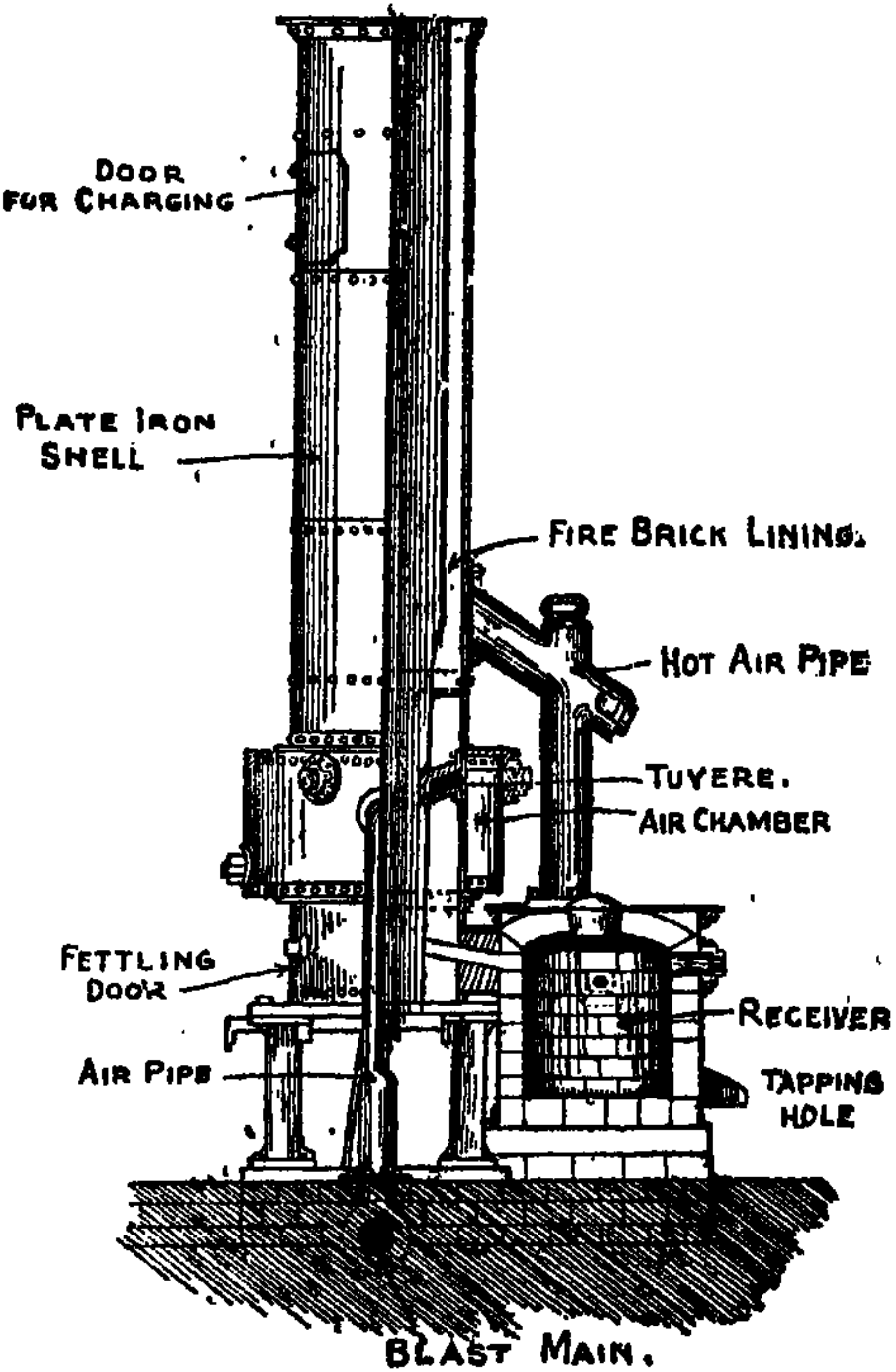
As already stated, pig iron is the product of the blast furnace. These bars or pigs consist of pure iron and carbon both chemically combined, and mechanically mixed, and of such impurities as silicon, sulphur, phosphorous, and magnesia, all of which, even though present in minute proportions, considerably affect the nature of the material. Thus phosphorous increases the strength, but makes the metal brittle, manganese improves the malleability, but the influence of carbon is by far the most important. When free or uncombined, it is visible as black specks, when chemically combined it is not visible. The effect of the free carbon is to render the pig easily fusible. The combined carbon renders the iron hard and brittle.

Cast Iron.

Cast iron is obtained by re-melting the pig iron in a "cupola", and running it into moulds of the shape required. The cupola (see Plate 6) is similar to the blast furnace in its action. Limestone is added as a flux which combines with some of the impurities left in the pigs

Plate. 6.

CUPOLA.



and removes them in the form of a slag. Cast iron is hard and brittle. Fuses at 2000° F. cannot be forged or welded. Most suitable for resisting compression such as in columns, bedding plates, shoes, etc. Unsuitable for resisting tension. Easily melted and run into various shapes such as railings, grates, pipes, gutters, or ornamental work of all kinds. Contains from 2 to 6 per cent. of carbon. The ultimate compressing strength averages from 38 to 55 tons per square inch. The ultimate tensile strength varies from 5 to 17 tons per square inch.

Definitions.—The following terms occur frequently while noting upon the strength and properties of iron and steel; their definitions are therefore given below:—

Load is the external force or combination of external forces acting on any piece of construction under consideration.

Stress and Strain.—The effect of a load is to change the shape or dimensions of the piece of construction upon which it acts and this change of shape or dimension is called a *Strain*. The internal forces called into action in the material of any piece of construction to resist the load are called *stress*.

There are three kinds of *strain* and *stress*—(1) Tensile. (2) Compressive. (3) Shearing.

Tension is the stress produced by pulling. It elongates the body upon which it acts and tends to cause rupture by tearing.

Compression is the stress produced by pressure. It shortens the body upon which it acts and tends to cause rupture by crushing.

Shearing stress is that produced when one part of a body is pressed or pulled so as to tend to make it slide over another part.

Tenacity is the resistance, due to the cohesion of the particles, which a body offers to being pulled asunder.

Ductility is that property of a material which allows of its being drawn out by tension to a small section.

Brittleness is lack of ductility or the tendency to break suddenly under stress.

Elasticity.—A material is said to be perfectly elastic if the whole of the *strain* disappears when the stress is removed.

Elastic limit is that stress which, if exceeded, the material no longer returns to its original dimension.

Permanent set is the permanent strain which remains after the removal of a stress which exceeded the elastic limit of the material.

Modulus of Elasticity is the ratio of stress to strain.

Ultimate stress is that which produces fracture.

Working stress is the maximum stress to which the material is subjected in actual practice.

Factor of safety is the ratio of ultimate stress to working stress and depends on the nature of the load which may be a *dead load*, a *live load*, or a *variable load*.

Malleability is the property of being permanently extensible in all directions by hammering or rolling.

Weldability is the property possessed by some metals of adhering firmly to portions of the same or other metal when the two pieces are raised to a high temperature and hammered together.

Wrought Iron.

Wrought iron is obtained by extracting from pig-iron the greater part of its carbon and other impurities, by melting in a reverberatory furnace. (*See* Plate 7.) In this furnace the metal is subjected to the heat of the flame and a strong current of air. The fuel is kept quite separate from the metal. The molten metal is well mixed with oxidising substances, *e.g.* hæmatite ore, iron oxide, forge scales, and sometimes with limestones and salt. The oxygen in these combines with the carbon left in the iron, and also with the silicon, forming slag, which is run off. The iron becomes less fusible as the carbon is removed and becomes pasty and is then worked up into balls, or "blooms" as they are called. These blooms are subsequently welded into a compact mass, and the remaining slag and cinder eliminated by blows from the steam hammer or by passing between grooved rollers This process is known as *puddling*. These puddled bars produced by rolling are wrought iron, but of the lowest class. The grade of the wrought iron depends, up to a limit, on the number of times this process of reheating and re-rolling is performed.

Market forms of wrought iron and steel.—Wrought iron and steel are prepared in a variety of convenient forms for the market, the more important of which are mentioned below and sketches are given in Plates 8 and 9.

Bar iron (round, square and flat) is manufactured in lengths up to 30 feet.

Rounds and squares increase their section by sixteenths of an inch from ½ up to 3 inches, and by larger intervals up to 7 inches.

Flat sections vary from 1" × ¼" to 6" × 1", the widths increasing by eighths of an inch at the same time that the thickness increases by sixteenths of an inch, and from 3" to 10" wide up to 1½" thick.

Rail Bars are of various sections, *e.g.*, *doubled headed* or *bull-headed rail*, *flat bottomed rail*, *tram rail*, etc.

Equal Angles may be had in lengths up to 45 feet and of sections varying from 1¼" × 1¼" × $\frac{3}{16}$" to 8" × 8" × ¾".

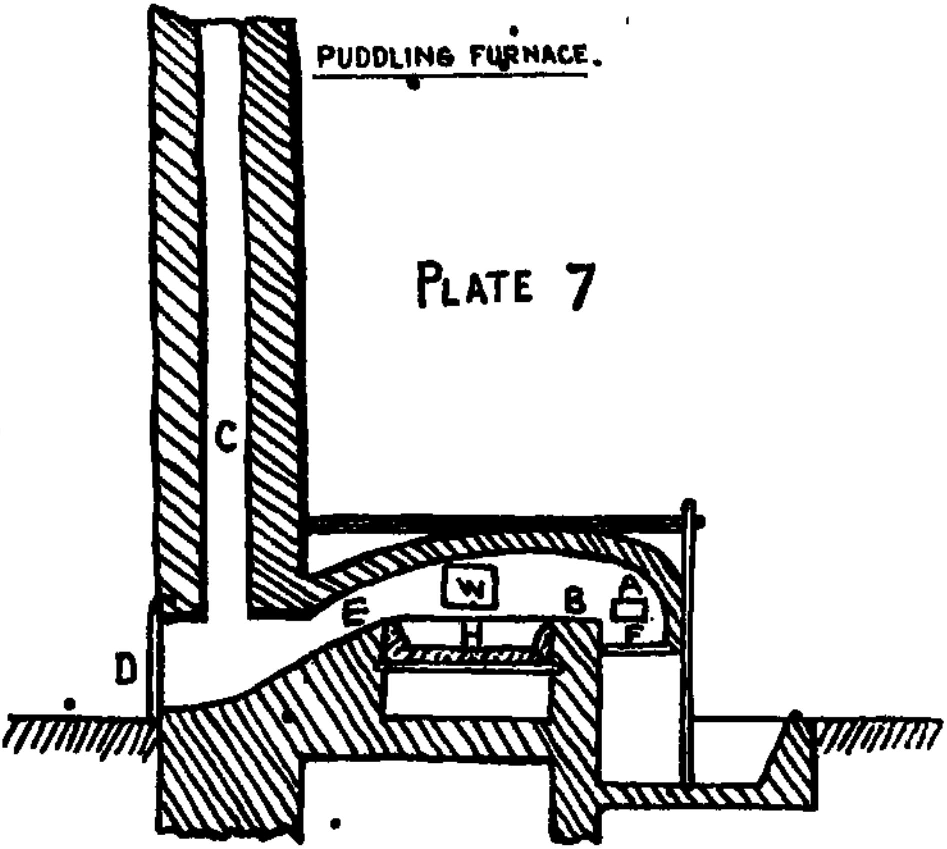
Unequal Angles have sections varying between 2" × 1½" × $\frac{3}{16}$" to 7" × 3½" × ⅞".

Tees can be had in lengths up to 40 feet, and sections vary between 1½" × 1½" × $\frac{3}{16}$" and 6" × 4" × ⅝".

Channels up to 35 feet in length and sections varying from 2" × 1" to 15" × 4".

Rolled joists may be had in depths from 3 to 20 inches. A very great variety of sections is kept by different manufacturers who generally publish full size sections giving detailed information regarding dimensions and properties, of each of the forms enumerated above.

Plates range from $\frac{3}{16}$" to 1" in thickness increasing by sixteenths. The area does not usually exceed 24 feet.



PUDDLING FURNACE.

PLATE 7

A = FIRE HOLE
B = FIRE BRIDGE
F = FIRE GRATE
C = CHIMNEY
H = HEARTH
W = WORKING DOOR
E = FLUE-BRIDGE
D = DOOR FOR REMOVAL OF SLAG

PLATE. 8.

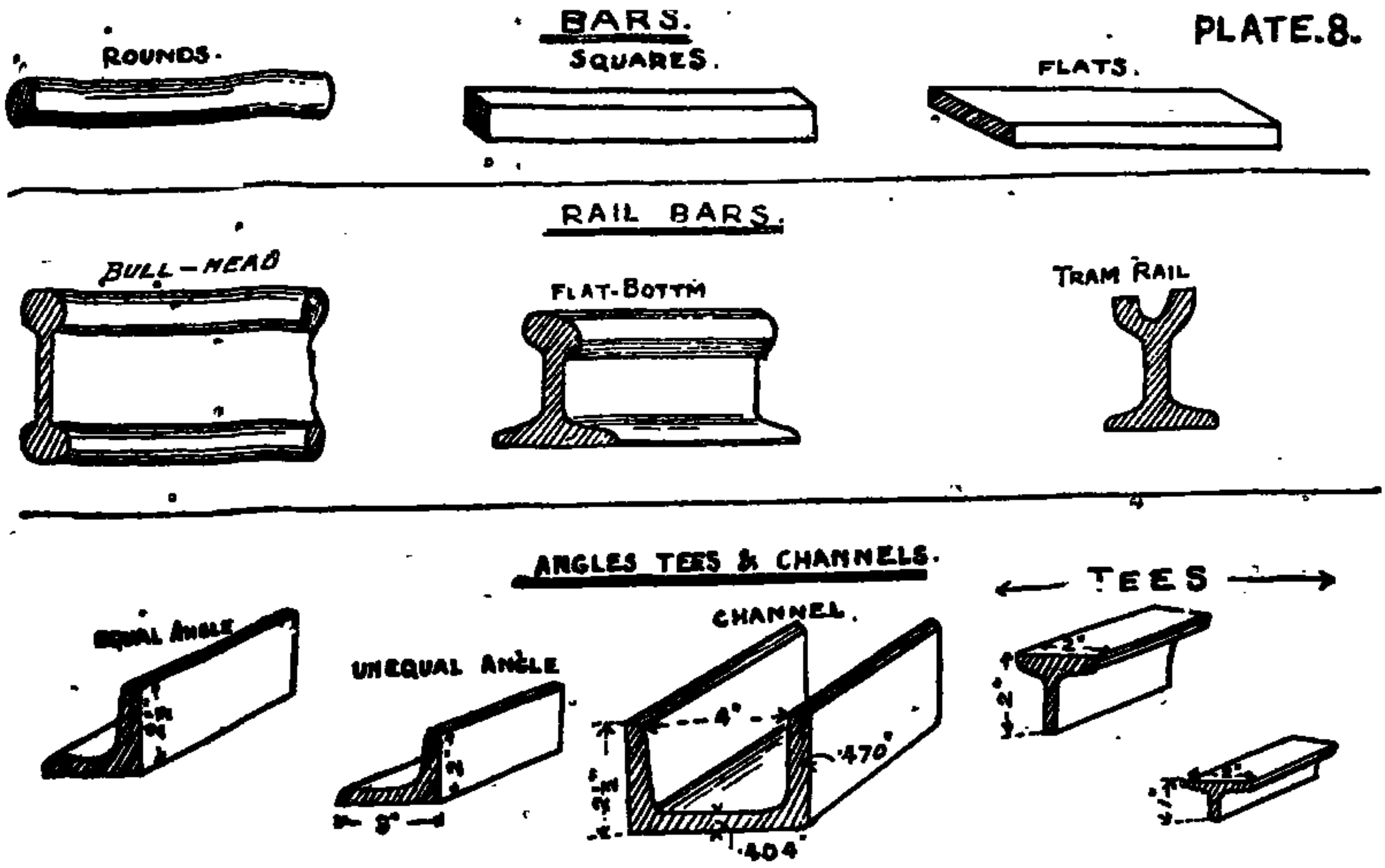
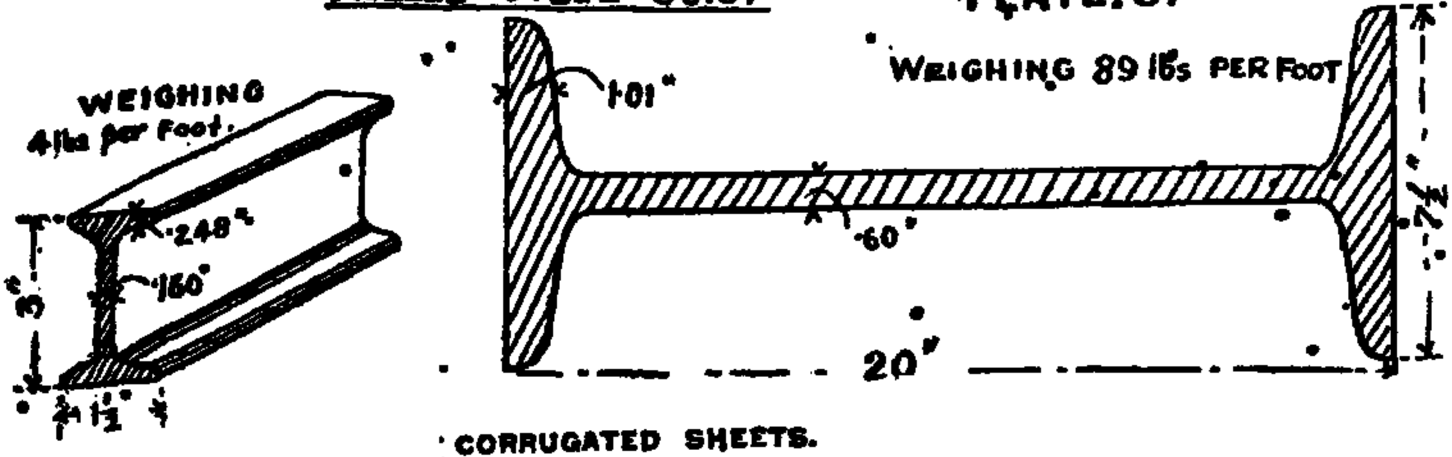
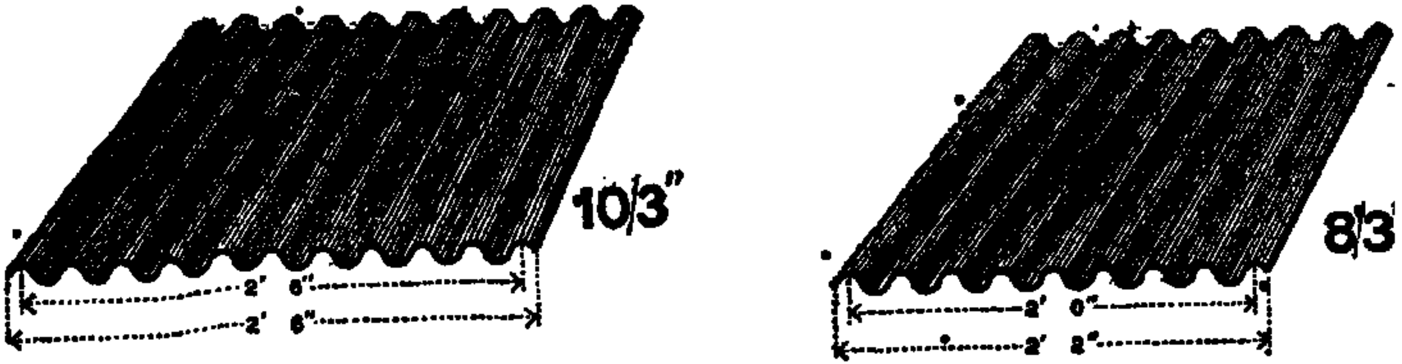

BARS.
ROUNDS.
SQUARES.
FLATS.
RAIL BARS.
BULL-HEAD
FLAT-BOTTM
TRAM RAIL
ANGLES TEES & CHANNELS.
EQUAL ANGLE
UNEQUAL ANGLE
3"
CHANNEL.
4"
·470"
·404"
TEES
2"
2"
2"

PLATE. 9.

ROLLED STEEL JOIST



CORRUGATED SHEETS.



Sheets (as distinguished from plates) are sold in thicknesses of $\frac{1}{16}''$ and $\frac{1}{8}''$. Plates and sheets exceeding 4′ in width or 20 feet in length or weighing more than 9 cwt. cost extra, but can be obtained up to 7 feet wide or 35 feet long up to 2 feet wide. Sheet iron is largely used for roofing and other purposes in India.

Corrugated sheet iron is made by passing sheets through grooved rollers which bend them into parallel waves or corrugations. The corrugations increase the stiffness and strength of the sheets considerably.

Galvanised iron is iron covered with a thin coating of zinc. Both plain and corrugated sheets are generally galvanised. Galvanising preserves the iron from corrosion by rust. When iron is oxidised it is said to be rusty. Iron will not oxidise in dry air or when wholly immersed in water free from air, but will rust when alternately exposed to moisture and air.

The average ultimate strength of wrought iron is as follows :—

Tension, 25 tons per sq. inch.
Compression, 18 tons per sq. inch.
Shearing, 20 tons per sq. inch.

It may be preserved by galvanising or painting. Before painting it should be freed from any scale which may have formed on its surface.

Wrought iron is suitable to resist tensile stresses and has been much used for roofs, girders, long stanchions, etc. Its reliability has been its great recommendation, but it is now being displaced by steel.

Steel.

Definitions.—Steel may be defined as malleable combinations of iron and carbon which permit of being hardened, tempered and cast into malleable ingots.

Steel may be divided under two main heads, *Mild steel* and *Hard steel*.

Mild steel includes shear and steels made by the Bessemer and Siemen process. Hard steel includes the crucible cast and the Whitworth compressed ingot.

Manufacture of Mild Steel.—Mild steel is produced by three distinct processes—

(1) **The Cementation process** is that by which cast iron is first refined into an almost pure wrought iron. The latter is then changed by combining with a definite amount of carbon.

(2) **The Bessemer process.**—By this process steel is made from pig iron.

(3) **The Siemen's or open hearth proess.**—Iron ore rich in oxide, pig-iron and sometimes steel scrap are the ingredients for producing steel by this method.

Generally.—Mild steel is suitable generally for constructional purposes, *e.g.*, bridges, girders, roofs. In particular, Bessemer steel for rails, axles, common tools, boiler plates, etc.

Siemens for rails, tyres, boilers, forging for engines, tin plates, girders, etc. Hard steel is useful generally for cutting tools. In particular crucible cast steel is used for the finest cutlery and for cutting tools composed of steel only, where great hardness is required.

Whitworth compressed steel is used for boilers, rivets, guns, parts of large machines, boring tools, etc.

The amount of carbon in steel varies from ·10 for very soft to 1·5 per cent. for very hard steel.

Steel may be distinguished from iron by dropping dilute nitric acid on the surface. If the metal is steel a dark grey stain will be produced. Steel is highly elastic, malleable, ductile, forgeable, weldable, capable of receiving different degrees of hardness by tempering, fusible at a lower temperature (240° F.) than wrought iron.

Hardening, tempering, annealing and **case-hardening.**—Steel at a red heat when plunged into cold water becomes excessively hard. The more suddenly the heat is extracted the greater will be the degree of hardness. The degree of hardness also depends upon the percentage of carbon present.

This process of *hardening* makes the steel brittle and it is therefore necessary to resoften or to *temper* the metal before use.

Tempering is of great importance in the manufacture of cutting tools, steel springs, etc.

The article to be tempered is first hardened as described above and then slowly heated to a moderate temperature and allowed to cool. When cooled from a high temperature it is softer than when cooled from a low temperature. The film of oxide formed on the surface of the steel when heated becomes thicker and changes in colour as the temperature rises.

The colour of this film is therefore an indication of the temperature, and therefore of the degree of hardness or temper required.

Annealing or softening steel is effected by raising hardened steel to a red heat and allowing it to cool gradually. By this process it regains its original softness.

Case-hardening is the process by which the surface of wrought iron is changed to steel. The article to be case-hardened is placed in an iron box containing bone dust and subjected to a red heat for a period which depends upon the depth of steel required. This period varies from ¼ hour to 8 hours and the depth of steel from $\frac{1}{16}$ to ⅜ inch.

The surface of an article treated this way is rendered hard and capable of resisting wear. Keys, gun locks, bearing parts of bicycles, link work of locomotives and other articles requiring a hard surface combined with toughness are generally case-hardened.

Copper.

Next to iron, copper is the most important metal used by engineers.

Properties.—Copper is of a reddish colour, takes a bright polish, but oxidises slowly in air, being covered by a film of carbonate ("verdigris").

Salt water corrodes it if the air has access at the same time. It is highly malleable and ductile. Can be worked cold or hot. Cannot be welded. Its high conductivity for heat and electricity makes it eminently suitable for electrical purposes. It can be drawn into moderately fine wire.

Uses.—It is used for nails, bell wires, lightning conductors, bolts, locomotive fire boxes, tubes, etc. It is in the manufacture of alloys such as brass and bronze that it is most widely used by the engineer.

Market forms.—Copper is prepared for the market in the form of ingots, sheets, wire cord and tubes.

Lead.

Manufacture.—Lead is reduced from ores, chiefly from one called Galena (sulphide), by roasting or smelting in a reverberatory furnace.

Properties.—Lead is an extremely soft and plastic metal, heavy fusible, very malleable but wanting in tenacity and elasticity.

Uses.—Lead is used for covering roofs, bedding girders, pipes and cisterns. It is also used in the preparation of white lead (lead-carbonate) which forms the base for many ordinary paints.

Zinc.

Manufacture.—Zinc is prepared from ores by roasting and subsequent distillation with carbon.

Properties.—Zinc is easily fused. It is brittle when cold and at high temperatures (about 400°F.), but it is malleable at about 220°F. and can be rolled into sheets.

In the presence of moist air a film of oxide is formed on the surface of zinc. This film protects the metal from further action. The zinc is destroyed if the air contains acid or soot. Good zinc is tough and of uniform bluish grey colour free from blotchy particles of darker colour.

The presence of lead makes it impossible to roll zinc because of its brittleness.

Zinc containing more than 1 per cent. of lead should be rejected. If laid in contact with iron, copper or lead a voltaic action is set up which destroys the zinc rapidly in the presence of moisture. Zinc expands and contracts more than other metals when subjected to changes of temperature.

It blazes furiously if raised to a red heat.

Uses.—Zinc is used for roofing, pipes, cisterns, ventilators, slating nails, covering for iron to prevent oxidation. Its oxide is used as a basis for zinc paint, and it forms a component of many useful alloys.

Tin.

Manufacture.—Tin is obtained from tin pyrites and an ore called "Tin stone". The ore is stamped, then roasted, washed, a flux is added and after smelting in a reverberatory furnace the liquid metal is run off into moulds. The ingots thus produced are then refined.

Properties.—Tin fuses at a lower temperature than other metals. It is very malleable and oxidises very slowly. It is very soft and its ductility and tensile strength very low.

Uses.—Tin is used for covering steel plates and lining lead pipes. It is an important constitutent of alloys.

“Block Tin” or “Doubles” is used for the best tin ware. It consists of steel having a thick coating of tin.

Aluminium.

Aluminium is a silvery white metal, easily cast, malleable, ductile, very light, not easily corroded. Its chief use for the engineer is in the preparation of alloys.

Alloys.

Alloys are mixtures of one or more metals. Their properties are so different from those of their constituents that they cannot be regarded as merely mechanical mixtures.

For example a mixture of 9 parts of copper and one of tin gives an alloy (gun metal) which is harder and more fusible than copper, but which cannot be rolled. If tin is added to this mixture, its hardness is increased, in spite of the fact that it is a softer metal than copper.

Alloys are prepared by melting the more infusible metal first, the other (or others) being added later, and continually stirred to prevent the heavier metal from sinking which would result in an alloy that would not be homogeneous.

The tensile strength of an alloy is generally greater than that of its constituents.

Alloys produced by mixing copper and zinc are called “*Brasses*.” Those of copper and tin “*Bronzes*”.

Brasses.

Brass is one of the most important alloys. Its colour depends upon the proportions of its constituents.

Common *yellow brass* is generally used for castings, contains 2 of copper, and 1 of zinc.

Muntz Metal contains 60 parts of copper to 50 of zinc. It can be forged or rolled at a red heat, and it is used for sheathing ships, etc.

Delta Metal is tough and hard. It can be rolled hot or drawn into wire when cold. Makes fine castings and does not tarnish so much as brass.

Bronzes.

Bronze contains copper and tin, the proportions varying according to the kind of work for which it is required. The tin is first melted in twice its weight of copper to produce “hard metal” which is then added to the proportion of copper separately melted.

Gun Metal produces good strong castings and does not corrode.
Soft gun metal contains 9 parts copper to 1 of tin.
Hard „ „ 82 „ 18 „
Bell Metal.— „ 4 „ 1 „
Bell metal, as its name implies, is used for making bells.

Bronze is used for machinery bearings, stop cocks and valves, small toothed wheels, statuary, etc.

Other Alloys.

Phosphor Bronze is an alloy of copper and tin with a small percentage of phosphorous. Its strength is nearly equal to that of wrought iron. It can be cast, forged or drawn into wire. For ordinary work its composition is copper 85, tin 15, phosphorous 0·5. It is useful in positions subject to shocks. It wears longer than gun metal when used in bearing.

Babbits Metal consists generally of about 81 per cent. tin, 4 per cent. copper and 7 per cent. antimony. It is used for lining bearings. It is very soft, wears smooth, and reduces friction.

Solder is an alloy used for joining pieces of metal, the junction being effected by the solder combining with the metals to be joined and forming a fresh alloy with them.

The composition of solder varies according to the nature of the metals it is desired to unite.

Hard Solders are those which fuse at a red heat, and are used therefore for uniting metals that will endure that temperature.

Soft Solders melt at low temperatures and may be used for nearly all metals. The joint will be stronger the more nearly the solder agrees with the metal to be united in hardness and malleability.

Soldering.—The process of joining two or more pieces of metal together is called *soldering*. It is essential that the surfaces to be joined should be carefully cleaned and free from oxides. When the surfaces are heated they are easily oxidised, and it is therefore necessary to prevent this oxidation by means of a *flux*. The flux used for hard soldering is Borax.

Brazing.—The process of making joints in iron, copper, brass and gun metal with hard solder is called *brazing*, and is generally performed by heating in an open air hearth or by means of a blow pipe if gas is available.

Granulated solder and borax with a small quantity of water is the flux generally used.

CHAPTER IV.

Timber.

Classification of Trees.—"Timber" and "wood" are terms used by engineers to indicate the product of certain trees after they have been felled, shorn of their branches, and stripped of their bark. The trees are known by popular names in the language and country of their growth, and their product as timber often receives different names thus causing confusion. The scientific names of trees are therefore of assistance in identifying them, but are of no practical assistance in distinguishing the timbers.

Structure and Growth of Trees.—A knowledge of the effects of growth on the structure of timber trees is important in that it explains why (1) one wood is stronger than another, (2) why wood may be stronger in one direction than in another, and why woods vary in their characteristics while undergoing seasoning or in working. A tree may be divided into roots, trunk, branches and leaves. The roots serve the double purpose of anchoring the tree to the ground and of absorbing from the latter the food necessary for its sustenance. The trunk is the channel by which the food is supplied to the branches, and leaves, where under the action of light and air, the food is prepared in a form which can be assimilated by the tree.

This "food" is called sap, and consists of such substance as starch, resin, gum, etc., after it has been transformed under the action of light and air.

The sap absorbed by the roots travels to the topmost leaves where it is transformed into resin, gum, etc., as described above, and returns to the roots again. This circulation of the sap in the course of each year marks a distinct stage in the growth, and the age of the tree may be estimated by the record left of these succeeding stages.

On examining the cross section, such as would be made by a horizontal saw-cut through the trunk of any ordinary timber tree four parts are noticeable. (*See* Fig 10.)

STRUCTURE OF TREES. FIG. 10.

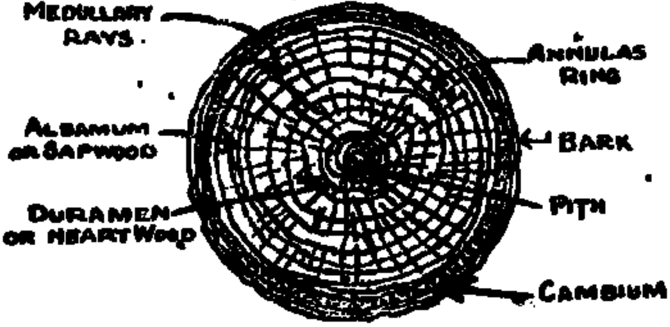
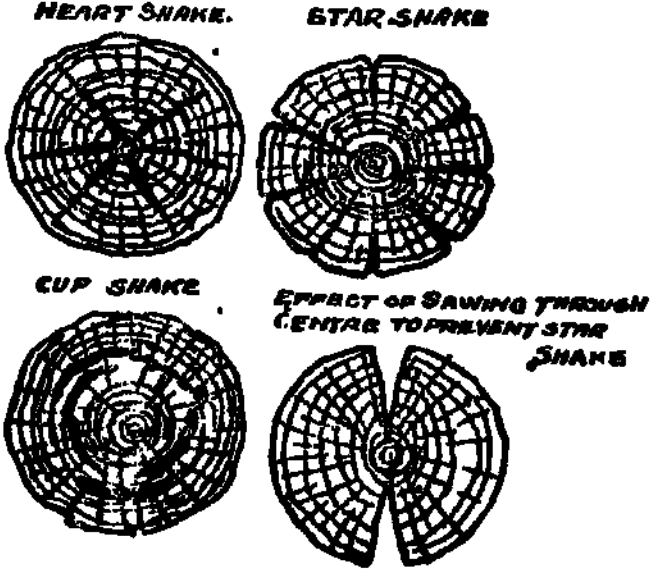


FIG. 11.

DEFECTS IN TIMBER



1. Pith or Medulla.
2. Medullary Rays.
3. Annular Rings { Duramen. / Alburnum.
4. Bark.

The *pith* or *medulla* is the first portion of the stem which is formed. It consists of cellular tissue and contains the fluid which serves to nourish the tree. As the tree gets older the sap and moisture are carried by the vessels of the woody fibre deposited about the pith and the latter having handed over its work, dries and decays.

The pith of all the branches is merely a continuation of the pith of the main stem.

Medullary Rays are vertical layers of cellular tissue, which radiate from the pith (or medulla) to the most recently formed layers and sap wood. Their function is to take the sap and air to the intertior vessels of the tree to complete the formation of the various tissues.

Annular Rings consists of cellular tissue and woody fibre arranged in concentric circles or rings about the pith. They are called annular because in-temperate climates one layer is formed annually.

In India or any other tropical climates, where the leaves are often shed twice in the same year, there would be a corresponding number of rings added. The rings are produced by the changes wrought during the circulation of the sap, which in the spring is absorbed from the soil and ascends to the topmost branches, and towards the end of summer descends in the outer layers of the tree, under the bark as already described above. The first formed annual rings are gradually filled with the substance carried into them by the medullary rays, and there harden to form "*Duramen*" or *Heart wood*.

The *alburnum* or sap wood should not be used for joinery because the sap has not solidified and would readily decompose.

The Bark consists of cells of woody fibre. A fresh layer is added annually on its inner surface. The bark increases in girth as the tree grows, but not at the same rate, so that in time the older layers split. In some trees the bark is thick and spongy as in the case of those trees that supply cork.

Time for felling trees.—From what has been said above it will be gathered that the best time for felling a tree is when the moisture and sap are at a minimum, *i. e.*, in the mid winter in temperate climates, and in the hot weather, in India. All other seasons are bad especially spring when the tree contains the maximum of sap. A tree should not be felled until it is in its prime. If too young there is too much sapwood. If too old the wood is brittle and lacks elasticity. It requires experience to judge whether a tree is in its prime or not. Oak trees arrive at maturity when about 100 years old. The ash and larch between 50 and 100 years. Norwegian Pine is generally cut when between 70 to 100 years old.

Seasoning.—As soon as a tree is felled it should be stripped of its bark to allow of a more rapid evaporation, and should be stacked so that the moisture may be dried out and all sap that has not hardened thoroughly driven out before the wood is used. This process is called seasoning and is necessary to prevent shrinkage and subsequent decay. The strength of green timber is doubled by the care taken in seasoning. There are three methods of seasoning in common use. Two methods are described below.

The natural method, which is also the best, consists in stacking the timber in such a way as will allow free circulation of air about all its faces. The stacking is done in sheds, the timber being placed perfectly level in racks. This method takes a longer time than the other, but the wood is more durable and reliable than that which is seasoned by any hastening process. The time required for natural seasoning varies from three months to two years according to the size of the timber.

Water seasoning consists in submerging the timber in a running stream with the butt end up stream, thus allowing the water to enter the pores more readily than it would if the tips were facing the current. The sap is diluted and carried out by the flowing water. The durability of the timber will be effected if kept under water for a longer period than 14 days. The timber is now stacked and left to dry by the natural method, the drying taking place much quicken after submerging. "Shakes" are liable to occur if the timber is dried too suddenly; the exterior surfaces dry and shrink while the interior is full of moisture.

Defects.—Timber may appear sound and yet contain the germs of disease which only await a favourable opportunity for development. The following are the most common defects :—

Heart Shakes are wide splits running right through the heart of the tree and indicate that the tree has passed its prime and that decay has begun at the centre. (*See* Fig. 11.)

Star Shakes are due to the shrinkage of the timber when seasoning, the splits radiate from the centre and increase in width at the outside edge. (*See* Fig. 11.)

Ring or Cup Shakes are gaps between the annular rings. They are caused by wind and frost in the growing tree. They are usually confined to the butt end of the trunk and are thus easily seen. If removed, the adjacent parts of the wood are not affected.

Rind Galls are curved swellings caused by growth over the wound made by imperfectly lopping off a branch.

Upsets are those portions of the timber in which the fibres have been injured by crushing.

Knots are a necessary accompaniment of the growth of a tree being the permanent record of its branches. They are called "live" or "dead." Live knots are the springing points of branches which were living when the tree was felled. Dead knots are the roots or springing points of branches that had died off before felling. Dead knots, if not already loose, are liable to become so.

Selection.—The selection or rejection of timber having defects as noted above will depend to a great extent on the purpose for which the wood is required.

Heart shakes, as forerunners of disease, are inadmissible, but in cutting up the logs to form planks, battens, etc., the defective parts are usually cut away. The effect of star shakes depends entirely on its extent. The worst objection to them is that they are liable to extend if the timber is not fully seasoned and is subsequently exposed to damp. For structural work therefore shakes must always be viewed with suspicion. Cup shakes, though found in the log, are seldom seen in timber supplied for structural purposes.

In regard to knots, their importance depends on whether they are "live" with their tissues closely knitted to the surrounding wood, or "dead" in which case they lack that union. In structural work dead knots are always a source of weakness, whereas the effect of live knots depends on their size and position. For example, if they occur on the under side of a beam where the wood is in tension their weakening effect may be material, but if on the upper side where the wood is in compression the result does not materially affect the strength for joinery, especially of the ornamental kind; live knots often introduce pleasant variations in an otherwise plain grained surface, but if they are resinous and the work is to be painted, special precautions have to be taken to prevent the resin working through. Dead knots, if properly secured or knocked out and the holes plugged cause disfigurement which however will be concealed by painting.

Conversion.—The cutting up of logs to form baulks, planks, battens, etc., is called conversion. The most economical method is to cut the logs longitudinally, the saw cuts being tangential to the annual rings. Hard woods, such as oak, often have their sections cut into quarters, and the pieces are cut with faces parallel to the long faces of the quarters. The engineer is usually able to purchase his timber after conversion in the form of logs, baulks, planks, battens, deals, ends, masts, spars, poles and prepared timber.

Decay and Preservation.—Matured and well seasoned timber, if protected from harmful, external influences is practically imperishable. Some of those harmful, external influences are :—Exposure to moisture and dryness alternately, which cause repeated swelling and shrinkage. This alternation of swelling and shrinkage results in the complete breakdown of fibre cohesion, rapid oxidation, and finally the timber is converted into powder. This form of decay is called "wet rot."

The most serious form of decay in timber is that known as "dry rot," a disease or fungus growth which is spread by germs. These germs are capable of lying latent for an indefinite period, until they find themselves in surroundings favourable for their growth. All timber, seasoned or otherwise, may be infected with these germs. Having once obtained lodgement, the germs await surroundings favourable to their growth. Such surroundings occur in warm, damp and unventilated situations such as in cellars, or beneath floors which are close to the ground and also where the wood is boxed in by air-resisting hard plaster.

All timber should therefore be well ventilated when fixed in position and thoroughly seasoned before fixing.

In India the most injurious insects are the white ants and the goon. The latter only attacks soft and unseasoned wood. The natural resistance of timber to decay is increased by artificial means.

Many chemical processes have been put forward, which consist of forcing various preservative and sterilising liquids, such as creosote, into the pores of the wood.

Generally in order to keep timber sound it should be kept free from all moisture and be well ventilated. Painting or tarring preserves timber provided the latter is thoroughly dry and well seasoned, otherwise it only confines the sap and moisture and causes rot.

Characteristics of good timber.—Good timber should be from the heart of a sound tree, entirely free from sap, the wood uniform in substance, straight in fibre, free from large and dead knots, flaws, shakes or blemishes of any kind. The colour of good timber is uniform throughout. Among coloured timbers, darkness of colour is said to indicate strength and durability. Good timber is sonorous when struck. A dull heavy sound indicates decay

Other notes.—All timber resting on or bedded in masonry should be well coated with boiling coal tar. The ends of all timbers set in masonry should have a space left on either side, to permit of free circulation of air round it.

No wood work of any sort should be set within 2 feet of a flue or fire-place.

The strength of the same kind of timber varies considerably depending upon the nature of the grain and amount of moisture present. One-fifth the breaking weight is the highest load that should be placed on timber. A factor of safety of 10 is taken for pillars, posts, etc.

The loss of water while seasoning timber gave rise to an old formula that wood is not sufficiently seasoned, *i.e.*, dry, until it had lost one-fifth of its weight if required for carpentry, and one-third if for joinery.

CHAPTER V.

Paints and Painting, Varnishes, Bolts and Nuts, Nails, Screws, etc.

Paints.

Definitions.—Paint is an impervious coat laid on the surfaces of wood, iron, and even stone work to protect them from the effects of the atmosphere, and also for decorative purposes.

Paints consist of :—

(*a*) a base,
(*b*) a vehicle or carrier,
(*c*) a drier,
(*d*) a colouring pigment,
(*e*) a solvent.

The *base* determines the character of the paint. The following materials are generally used in bases :—

White lead is that most used as a base for painting all ordinary building work. It has a greater covering power than other bases and weathers well, but is liable to discolouration by sulphuretted hydrogen and has objectionable poisonous properties for which reason its use as a base is forbidden in France.

Red lead is chiefly used as a priming coat for wood, and also as a base for some red paints. It is not durable when exposed to foul air, acids and metallic salts.

Zinc white is the basis of most zinc paints and is not liable to discolouration by sulphur as is the case with lead paints. It is however difficult to work, has less body than white lead and is less durable. Lead driers should not be used with zinc paint. It may be tinted with ordinary pigments and, if used judiciously, costs less than that of white lead.

Oxide of iron is used as a base in paints, chiefly for painting iron work. The tints obtainable vary from yellowish brown to black. One of the best known paints of this class is Olphert's oxide of iron paint, largely used for painting iron work.

Vehicles.—A vehicle is a liquid of a drying nature. It dissolves and holds the bases and pigments in suspension, and enables the paint to be laid on in thin uniform coats, and to enter the pores of the material where it hardens and forms a durable and impervious skin.

The oils generally used are linseed oil, poppy oil, and nut oil.

Driers.—Linseed oil dries by absorbing oxygen. This absorption of oxygen may be accelerated by adding substances containing a large proportion of that element, *e.g.*, litharge or red lead.

Litharge is most commonly used, the proportion being about ¼ lb to a gallon of oil.

Red lead is often used when its colour does not affect the tint.

Terebene is a solution of one of the driers in oil of turpentine. It is used for paints that are required to dry quickly.

Pigments are colouring matters, used to give opacity and tint to the paint for ornamental purposes. They consist of earthy metallic and animal substances, and are finely ground in oil for oil paints. The following are the most common :—

Blacks.—Lamp black, vegetable black, ivory black.
Blues.—Prussian blue, indigo.
Yellows.—Yellow ochre, chrome yellow, raw sienna.
Browns.—Burnt umber, raw umber.
Reds.—Carmine, red lead, vermillion.
Green.—Copper sulphate.

Solvent.—Oil of turpentine is used to thin prepared paints to make them work more smoothly. If used in excess it flattens colours which are not then durable. English turpentine is too pungent for indoor use.

Preparation of Paints.—The base is first thoroughly ground in oil and mixed with oil or spirits of turpentine to the required consistency. The pigment is now ground on a flat stone or in a colour mill with oil until thoroughly mixed and then rendered fluid by the addition of oil or spirits of turpentine and mixed with the base that has already been prepared.

Painting.—The preparation of the surface previous to painting requires as much supervision as the actual application of paint. The Shalimar Paint Company, Calcutta, give useful directions for painting in their pamphlet. Speaking generally, it is only necessary to paint wood work exposed to the weather and steel work. Wood oiling would suffice elsewhere.

All wood and iron work exposed to weather should receive four coats of paint. Three coats is sufficient for the interior work.

Paint should not be applied to wood work unless it is well seasoned. All surfaces to be painted should be thoroughly dry, clean, smooth and free from rust.

A priming coat, without colouring matter, should first be applied, after which all holes and cracks should be stopped with putty and all knots killed with quicklime.

For fine work each coat should be carefully rubbed with pumice-stone or glass-paper and dusted before the next coat is added. All paint should be laid on evenly with brushes ; the work should shew no hair marks or drops of paint ; each coat should be allowed to dry thoroughly before the next is laid on. Old work should be cleaned with limewash and rubbed down with pumice. If old paint is blistered, rub down and scrape. If it is greasy with smoke mix the first coat with spirits of turpentine instead of oil.

Varnish.

Varnish is a solution of resin dissolved either in oil, spirits, or water. It is used to preserve painted work exposed to the weather, and also to improve the appearance by covering it with a shiny transparent coat of resin. There are several kinds of resin used, the principal being amber, gum animo and copal.

Amber is hard, durable and tough, difficult to dissolve, slow in drying, keeps its colour well, but is very expensive.

Gum anime is durable, tough and hard, dries quickly but is subject to cracking.

Copal is considered the best. It is durable, tough and hard.

Driers.—Litharge or lead acetate is usually added to accelerate drying.

Good varnish should be quick drying, hard, tough, weather well, and have a good gloss.

The preparation of varnishes is difficult and it is better to purchase them ready prepared.

French polish is a varnish worked upon the surfaces of hard woods to heighten the effect of the grain. It is applied by rubbing on to the surface with wadding enclosed in linen rag. Varnishing should be done in dry weather as far as possible.

Oiling woodwork.—Oiling is much more economical than painting and may be adopted where conditions permit, *e.g.*, where the woodwork is not exposed to the weather. Frequent applications of raw linseed oil rubbed in well with rag gives a fine polish to woodwork.

The following forms a good oil coating for woodwork :—

3 lbs. double-boiled linseed oil.
1 lb. turpentine.
1 lb. beeswax.

The oil and wax are heated in a vessel over a slow fire till the wax is melted. When the mixture cools the turpentine is added.

Fastenings.

Bolts, nuts, rivets, washers, nails, screws.—Bolts are iron pins with a screw thread on one end and an expanded head at the other. By means of a *nut* the fastening is completed. There are numerous varieties of form.

Calling the diameter of the shank of the bolt *d*. the following proportions may be used :—Diameter of head 2*d*. ; depth of head ¾*d*., diameter of nut 2*d*., depth of nut *d*. ; diameter of washer 3*d*., depth of washer ⅛*d*.

Rivets are not so liable to become loose when subjected to wear as bolts and nuts, and are therefore preferable to the latter for constructional members that are not required to be taken apart. It is not usual to make rivets of a larger diameter than 1 inch. If required of greater diameter, bolts are used owing to the difficulty of snapping up the heads.

Rivets are made of the best wrought iron or mild steel either by hand or machinery and before they are fixed consist of a shank surmounted by a head, which latter may be cup-shaped or pan-shaped.

When the rivet has been made red hot and put through the hole it is to occupy, the tail end of the shank is formed to the shape required.

"Snap-headed rivets" are those having nearly hemispherical heads.

"Cup-headed rivets" or "snap rivets" are terms sometimes applied to the snap-headed rivets.

"Hammered rivets" have points finished to a conical form by hammering only.

Nails may be either cast, cut, or hand or machine wrought. Cast nails are made by running molten iron into moulds. Cut nails cut by machinery out of sheets of iron and some are forged. Wire nails are in very common use. Those having oval sections are valuable in that they have least tendency to split the wood.

Spikes are large nails used for heavy work.

Screws have advantage over nails in positions where it may be necessary to take the work to pieces, or where, the wood is liable to split.

Firms holding stocks of screws generally base their prices on "Nettlefold's Catalogue," at so many annas per shilling. For example the price of 2" iron screws No. 8 gauge listed at 2s. per gross would be eight annas per gross when the selling price is four annas per shilling. Screws of the same size in brass listed at 6s. 3d. per gross would be Rs. 2-5-6 per gross when the selling price is six annas per shilling.

Screws may be obtained in iron or brass in sizes varying from ¼" to 6", and with countersunk, round or square heads. Coach screws, for heavier work, may be obtained with square heads in lengths varying from 1½" to ¼". "Drive screws" are used for galvanised corrugated roofing, etc. They are driven like a nail and withdrawn like a screw. Illustrations of bolts, nuts, nails, spikes, screws hooks, hinges, hasps and staples, locks, etc., may be seen in any hardware merchant's catalogue.

Roofing felt.

Roofing felt.—Such as "Malthoid" or "Ruberoid" is extremely light, air tight and watertight, is used for roof covering. Obtainable in rolls 36" wide and 72' long in red or green colour and in 1, 2, or 3 ply, weighing 60 lbs. 85 lbs. and 100 lbs. respectively per roll. Each roll covers 200 sq. feet.

Door and Window Furniture.

"Parliament hinges" are useful to enable a door or window to be folded back against the wall. When ordering locks and latches is necessary to state whether right-handed or left-handed patterns are required. "Tower bolts" and "gate hooks" are often quoted at so much per inch of length per dozen.

Steel.—T-hinges are usually demanded by the number, but quotations are received as so much per cwt. The weights of different sizes are therefore required when making payments. The weights of such hinges are not usually found in engineering pocket books. Those noted below have been obtained from actual measurements :—

"Steel T hinges",	10"	weigh	9½	lbs.	per	doz.
	12"	"	10	"	"	"
	14"	"	22	"	"	"
	16"	"	24	"	"	"
	18"	"	27	"	"	"

"Norfolk latches" or a "thumb latches" are suitable for ordinary ledged doors.

"Hook and eye" or "band and gudgeon" hinges are used for hanging ledged and braced doors. In superior work a "Mortise lock" is used for panelled doors.

Each leaf of battened, framed and braced doors are hung with iron strap hinges, and are provided with iron bolts, hooks and eyes, all drop bolts and padlock. Brass butt hinges, bolts, handles, hooks and eyes are used for first class doors and windows. See illustration in any Hardware Catalogue.

Miscellaneous notes and Recipes.

Glue.—One lb. of glue melted in 2 quarts of skimmed milk resists moisture.

Powdered chalk added to common glue gives a strong glue.

Marine glue.—One of India-rubber, 12 mineral naphtha or coal tar Heat gently, mix and add 20 of powdered shellac. Pour out on a slab to cool. When required, heat to about 250°F.

Quick drying glue.—Break up the glue, dissolve in spirit of any sort without heat. Cork tightly. It will keep for years.

Rust joint cement.—2 salammonia, 1 flour of sulphur, 200 iron borings or filings.

To remove putty.—Paint it with nitric or hydrochloric acid. The putty may be removed with ease after an hour.

To remove old paint or varnish.—Apply a solution composed of ½ part soft soap, 1 part potash and ½ part quicklime.

The solution should be left on for 24 hours, after which the paint may be removed easily by washing with hot water.

Paint for black boards or Racquet Courts.—Lamp black 10 chittacks and turpentine 1½ chittacks. This will be sufficient to cover 100 square feet of surface. Produces a dull dead surface without shine and does not rub off on clothes etc.

PART II.

Use of Materials and Details of Construction.

CHAPTER VI.

Foundations, Walls, Arches, Bond.

Foundations are the bases of walls, columns, piers, abutments, etc., which are directly supported by the earth. The object of foundations is to prevent inequality of settlement, by distributing the weight of the structure equally over the earth. This is effected by making the foundation wider than the mass it supports, which also increases the stability and counteracts such damaging forces as *wind-pressure, unequal loading.*

Lateral escape.—Structures erected on soft soils, *e.g.*, sand, squeeze out the soil from beneath the foundation unless the soil is confined to the required area. This is usually done by sheet piling.

Sliding usually occurs where the building is erected on the slope of a hill. The weight of the structure is liable to cause the strata of soil to slide. This is prevented by building retaining walls.

Atmospheric action.—Where foundations are constructed on soils which are reduced to mud if exposed to the rain, they must be taken down below the surface of the ground to such depth as will be beyond the effects of the atmosphere. Four feet below the ground level is usually sufficient for this purpose.

Wind and other overturning pressures.—The width of foundations are increased so that the resultant thrust (of the over turning forces and the weight of the wall) falls within the middle third of the width of the foundation.

Soils.—The design of foundation varies with the nature and bearing strength of the soil. The following are approximate safe maximum pressures on foundations:—

Marsh land, quick sand, silt 0 to ½ ton per square foot.

Made ground, alluvial earth, damp clay, ¾ to 1 ton.

Ordinary earth, 1½ ton per square foot.

Firm clay, 2 tons per square foot.

Gravel and sand, soft rock, 2 to 3 tons per square foot.

Lime concrete	3 to 3½	"	"	"	"
Hard rock	8 to 18	"	"	"	"

The maximum pressure on foundations in Bengal is 1 to 1½ tons per square foot.

Excavation for foundations.—When trenches have to be dug in loose ground it is necessary to support the sides of the excavations. In "moderately firm ground" after a depth of say 4 feet this can be done by a few rough planks placed against the sides of the excavations and kept in place by wedging struts between them (*see* Fig. 12).

In "very loose soils" *e.g.*, sand or slipping clays, the planks or poling boards are usually put in horizontally as "sheeting" (*see* Fig. 13).

Width and depth of foundations.—In good soil it is seldom necessary to excavate more than 2 or 3 feet for the foundations of a single-storied building and 9 inches of concrete will suffice in really hard ground.

On sloping ground economy is effected by stepping off the foundation trenches as shown in Fig. 14, taking care to give sufficient over-lap where the concrete layers meet. For widening out brickwork the offsets are quarter brick in breadth (that is 2¼") and the height of each off set should not be less than two courses.

STRUTTING IN MODERATELY FIRM GROUND.

FIG. 12.

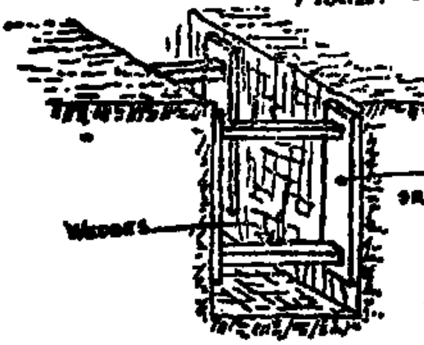


FIG. 13. SHORING IN VERY LOOSE SOIL.

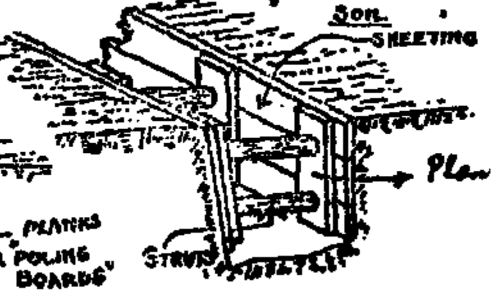
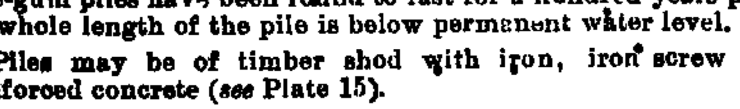


FIG. 14.

STEPPING OFF FOUNDS ON SLOPING GROUND

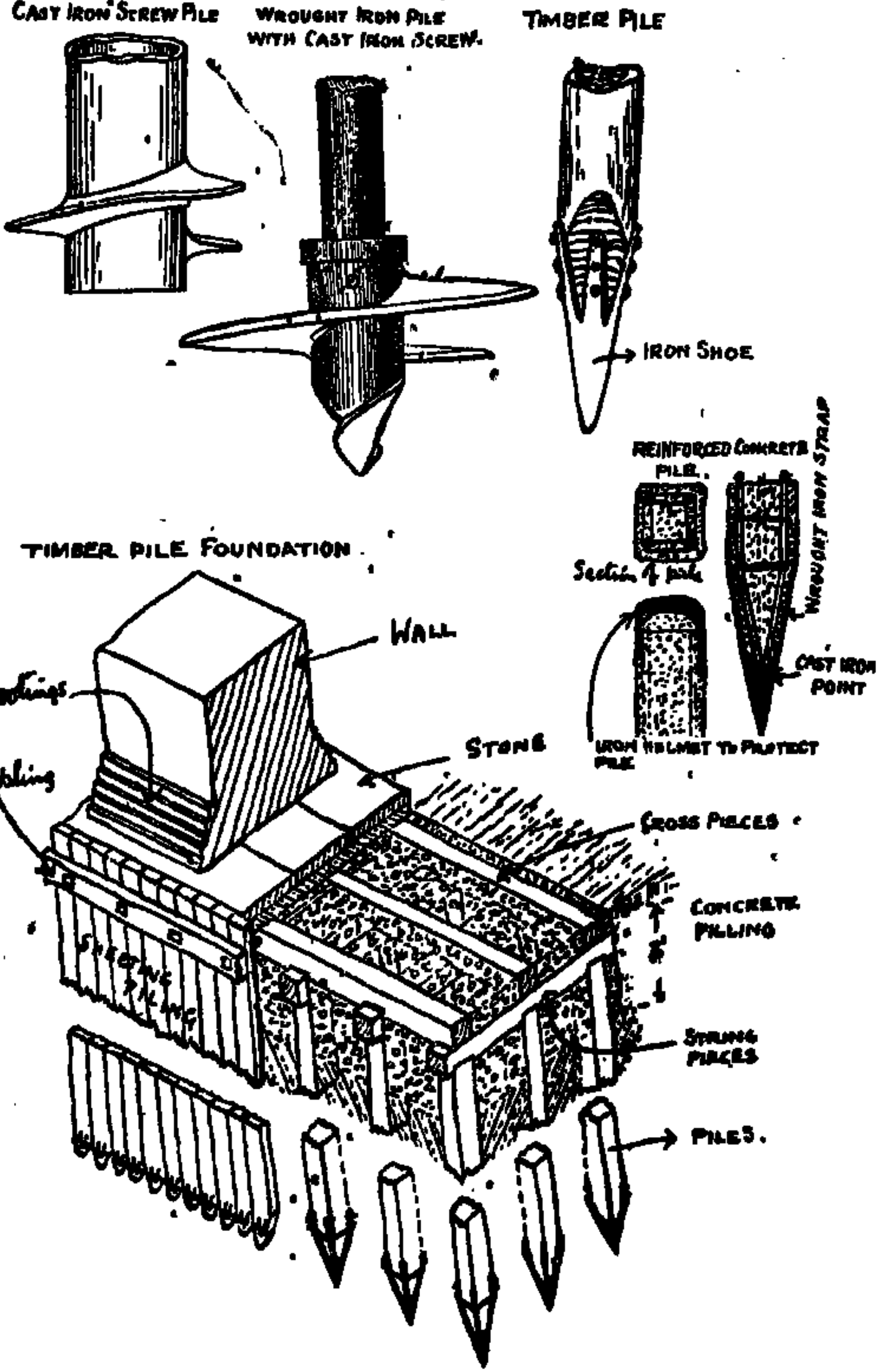


Pile Foundations.—In swampy ground piling may be necessary. Blue-gum piles have been found to last for a hundred years provided the whole length of the pile is below permanent water level.

Piles may be of timber shod with iron, iron screw piles or reinforced concrete (*see* Plate 15).

A portion of a timber pile foundation is shown in Plate 15. After the piles are driven and their heads sawn off level, a platform is generally laid on them so as to form a grating or "grillage." The ground between the piles is usually taken out to a depth of 3 feet and the space filled with concrete. Sometimes the platform is omitted and the bed of concrete takes its place. The piles are driven by a pile driver which consists of a falling weight (called a "monkey") sliding between upright guides.

PLATE. 15.


CAST IRON SCREW PILE
WROUGHT IRON PILE WITH CAST IRON SCREW.
TIMBER PILE
IRON SHOE
REINFORCED CONCRETE PILE.
WROUGHT IRON STRAP
Section of pile
CAST IRON POINT
IRON HELMET TO PROTECT PILE
TIMBER PILE FOUNDATION.
WALL
Footings
STONE
Waling
CROSS PIECES
CONCRETE FILLING
3'
SHEETING PILING
STRING PIECES
PILES.

Brickwork.

Definitions.—A "Stretcher" is a brick laid lengthways in the direction of a wall (*see* H, Fig. 16).

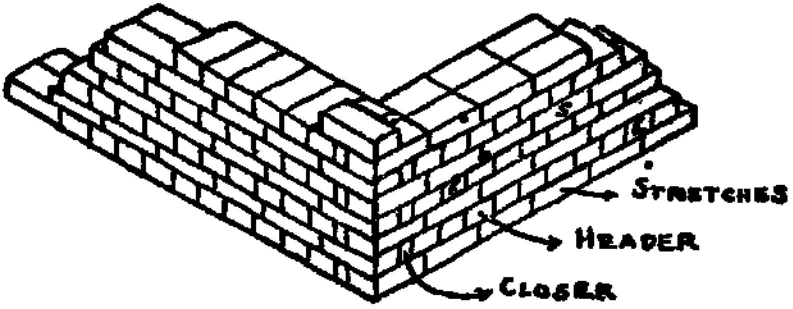
A **Header** is a brick running into a wall at right angles to the face (*see* H, Fig. 16).

A **Course** is any one complete horizontal layer of bricks in a wall.

Oversailing Courses are those which project beyond the face of the brick work below them course by course.

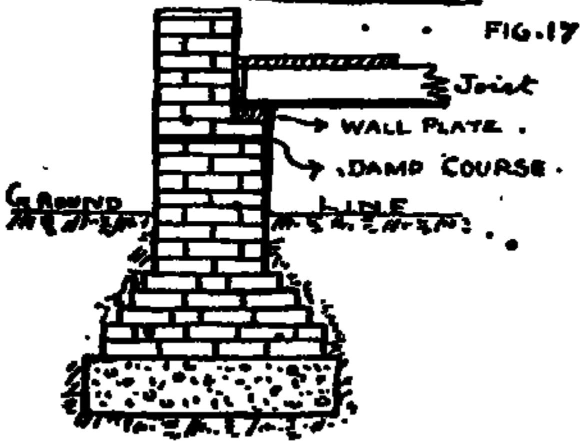
The damp proof course usually occurs from 6" to 12" above the surface of the ground but below the level of the lowest wall plate or other timber let into the wall. A half inch layer of asphalte, pitch, tar or bitumeous felt may be used, or even glazed tiles laid dry (*see* Fig. 17).

FIG. 16.



ENGLISH BOND

FIG. 17.



SECTION OF WALL AND FOUNDATION SHOWING DAMP PROOF COURSE AND OFFSET TO SUPPORT WALL PLATES.

String courses consist of ornamental bands of brickwork one or more courses in depth, sometimes differing in colour from the rest of the wall.

Queen closers are bricks cut in two length ways (*see* Plate 18).

King closers are bricks cut to the shape shown at X in Plate 18.

Bats are portions of bricks (*see* Plate 18).

Bond is the term applied to the arrangement of bricks in a wall so that continuous vertical joints are avoided.

Footings are the lowest courses of brickwork resting on a bed of concrete. They are made wider than the wall courses in order to distribute the pressure over as large an area as possible (Plate 15).

Coping is the top-most course of a compound wall or parapet wall. (*See* Plate 18.)

Offsets are ledges formed by the sudden reduction of the thickness of a wall at some point of its height. It is a common arrangement for supporting the lowest wall plate. (*See* Fig. 17.)

Corbelling consists in projecting successive courses of brickwork until a ledge is obtained. The projection should not exceed a quarter brick at a time. This method is sometimes adopted for supporting the wall plates of upper floors. (*See* Plate 18.)

Bond in brickwork.—The various kinds of bond (*e.g.*, English bond, Flemish bond, etc.) are only simple fixed arrangements in order that there may be no delay thinking how each brick shall be laid so that it may overlap and hold on to as many others as possible, and also in order that any number of men may work at the wall, and the work all fit in correctly. Each brick should close up as many joints as possible, both sideways in its own course, and downwards in the course below. Continuous joints being thus avoided, Plate 18 shows how this may be done in *English bond* for one brick or two brick walls, Plate 19 shows the arrangement of bricks in *Flemish bond*. It will be noted that *English bond* consists of alternate courses of headers and stretchers. The overlap is obtained by means of *Queen closers*; whereas *Flemish bond* consists of headers and stretchers alternately in the same course. The arrangement of bricks in *piers* is shown in Plate 19. The front elevation (*a b*) being turned to the side (*b c*) in alternate courses, except in the 1½ brick pier where the back elevation becomes the front.

Raking bond is of two kinds, *Diagonal* and *Herring-bone*. In the former the bricks in the interior of the wall are laid diagonally at such an angle with the face that the bricks will just fit in without being cut. (*See* Plate 19.) Herring-bone bond consists of bricks laid in the interior of the wall raking from the sides to the centre lines of the wall. (*See* Plate 19.) Neither of these bonds are used in practice for walls, but brick floors are sometimes arranged in either of these bonds.

General notes on Brickwork.—In no case should bricks of different dimensions be used in the same work. In first class work, no four courses of work, with three joints, should exceed in thickness when built one inch more than the same bricks piled one upon another without mortar. Bricks should be saturated with water before laying. All unfinished portions of brickwork in surki or hydraulic mortar or cement should be left flooded with about one inch in depth of water standing on it at the end of the day's work.

PLATE. 18

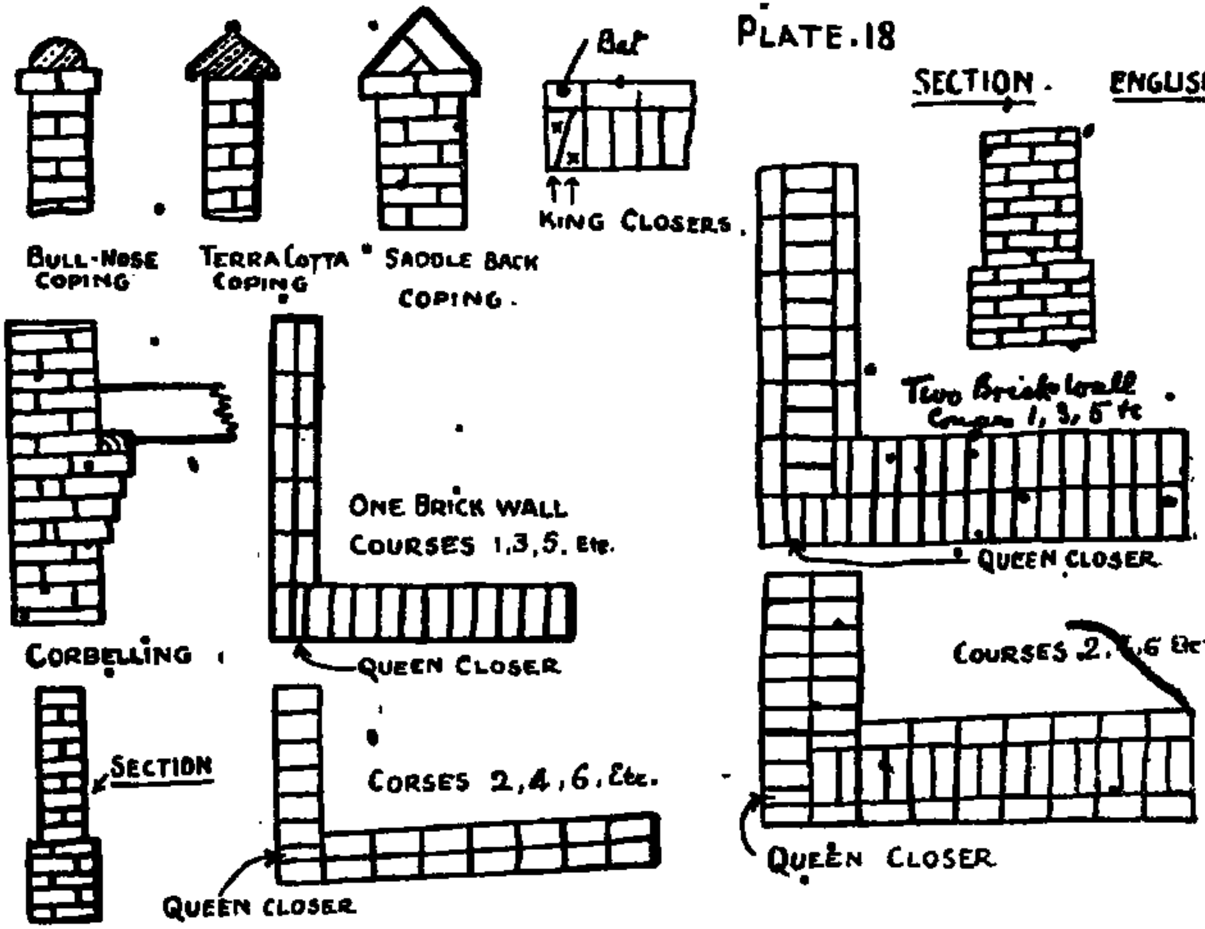
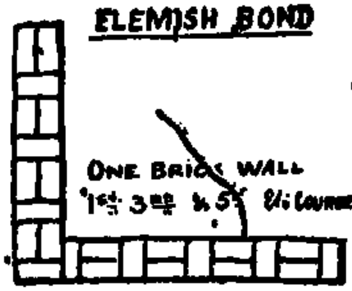
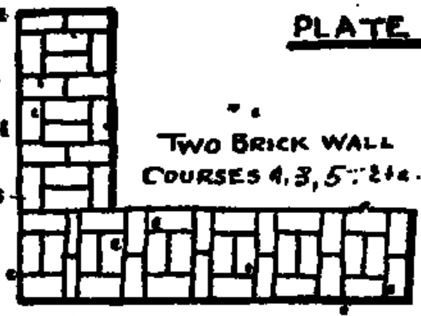
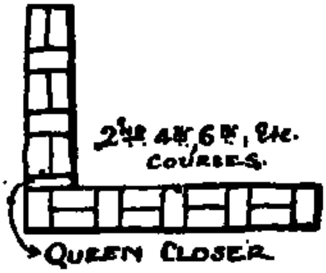

Bat
King Closers.
Section.
English Bond
Bull-Nose Coping
Terra Cotta Coping
Saddle Back Coping.
Two Brick wall Courses 1, 3, 5 Etc
Queen Closer
One Brick wall Courses 1,3,5. Etc.
Queen Closer
Corbelling
Courses 2.4.6 Etc
Section
Corses 2,4,6. Etc.
Queen Closer
Queen Closer

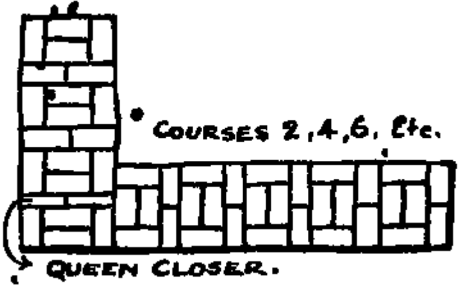
PLATE 19.

FLEMISH BOND

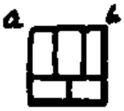




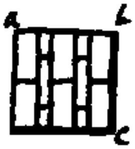




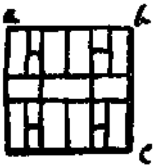
BRICK PIERS



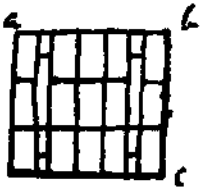
1½ Brick Square



2 Bricks Square

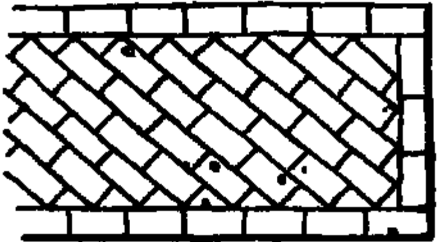


2½ Bricks Square

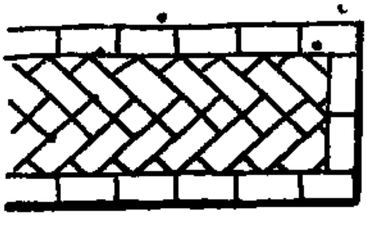


3 Bricks Square

RAKING BOND

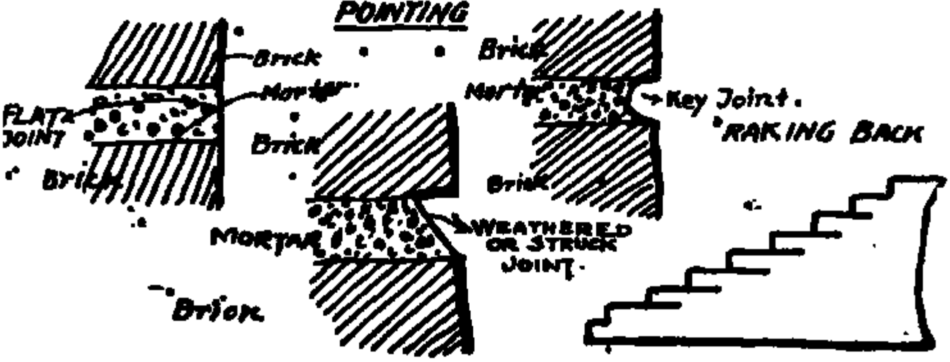


Diagonal Bond



Herring-Bone Bond

POINTING



The bricks should be thoroughly bedded and flushed with mortar. In good brickwork the joints should be about ¼ to ⅜ inch thick. The mortar should be raked out of the joints at least ¾ inch deep, and dust brushed out and the work well wetted and washed with water. The mortar to be used for pointing should consist of equal proportions of lime and fine sand in the case of lime pointing and equal parts of Portland cement and sand in the case of cement pointing. The joints should be neatly defined by the pointing and the lines regular and uniform in breadth. The joints may be raised or flat. Plate 19 illustrates three methods of pointing. The weathered or struck joint is the simplest. Its object is to throw rain off the horizontal joints by sloping the mortar back and upwards as shown.

Plaster.—When the face work has to be plastered, the joints should be well raked out before any plaster is laid on. Mortar for lime plaster should be made of fat or shell lime. After raking out the joints to a depth of at least ¾", the wall is washed with water and kept thoroughly wetted for six hours before plastering is commenced. A rendering of plaster, sufficiently thick to cover by ¾" all projections (½" is sufficient for brickwork) is applied in an even and uniform layer and well beaten for 1½ days with hand tappers, the plaster being wetted occasionally with fresh water while the beating is in progress. Over this a mixture of fine lime and white washing lime (proportion 2 : 1) is laid, made smooth, and very lightly beaten. Finally the finishing coat, consisting of one part fine lime and two parts white washing lime, is applied and well polished with trowels. The complete plaster should be allowed to rest for 24 hours and then be sprinkled with water at short intervals for 4 or 5 days.

Cement plaster.—The walls are prepared as described for lime plaster. "Render" with a mortar of equal parts of Portland cemen and fine sand 1" thick, and roughen but do not beat. "Float" o "set" with a thin coat ⅛" of Portland cement, and polish wel with a trowel or flat board. The cement should be used withi three hours after it leaves the mixing board or mill.

Brickwork.—The walls of all structures should be carried u regularly in all cases when the nature of the work admits of it, no leaving any part 3' lower than another. If, however, it i necessary to carry on the same section of a building in uneve courses, the breaks should be racked back so as to maintain a unifor and effectual bond. (*See* Plate 19.)

Parts of walls.—Quoins are the bricks (or stone) forming th external corners of a building. They are frequently made conspici ous by slightly projecting them. (*See* Plate 20.)

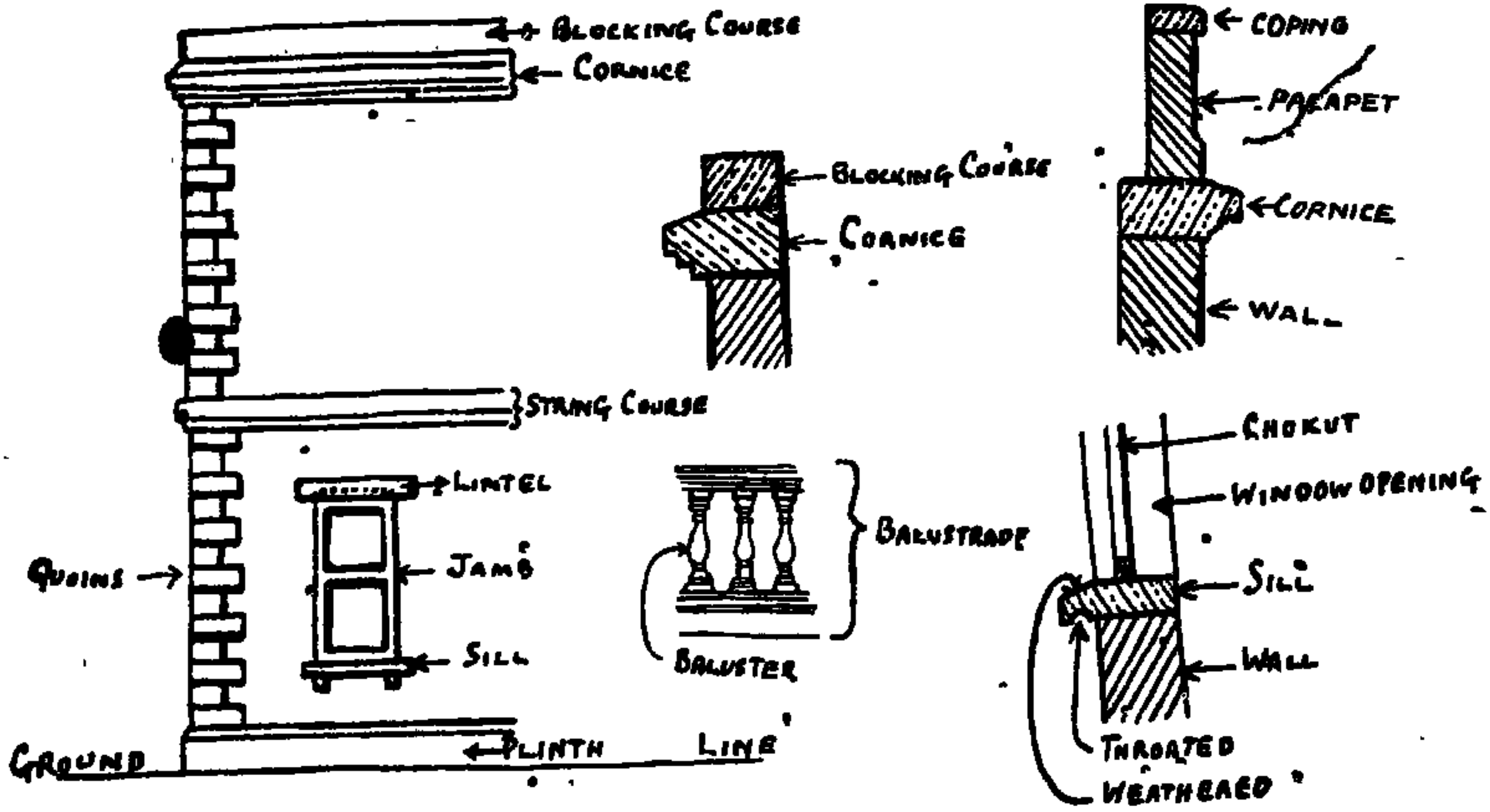
A "parapet" is a low wall built above the cornice which run round a building at the edges of a terraced roof. Its object i to present a finished appearance [illegible]he top of the main external wall (*See* Plate 20.)

A "balustrade" serves the same purpose as a parapet, but, unlik the latter, it is pierced to show a row of small ornamental columns o "balusters." (*See* Plate 20.)

A "cornice" is an ornamental projecting course at or near th top of a wall. (*See* Plate 20.)

PLATE. 20.

PARTS OF A WALL



A "string course" is also an ornamental projecting course carried round a building at the level of the different floors. (*See* Plate 20.)

"Jambs" are the vertical sides of doors and windows. (*See* Plate 20.)

"Lintel" is the name given to the horizontal support above the door or window opening (*see* Plate 20).

"Sill" is the floor of the opening. The sills of windows should project slightly beyond the face of the wall and be "weathered" and "throated" to throw off their drip from the wall below. (*See* Plate 20.)

Arches.

Definitions.—An "arch" is a system of blocks over an opening so arranged as to mutually support each other and to transmit their own and any superincumbent pressure to the supports at the sides of the opening. These blocks, whether of brick or stone, are called "voussoirs." When there is an odd number of voussoirs the centre one is distinguished as the "key stone." The upper surface of the voussoirs is called the "extrados." The under surface of the voussoirs is called the "intrados" or "soffit." The summit of the arch is called the "crown," and it is flanked on each side by the "haunches."

The sides of the opening are termed "jambs." The horizontal extent of the opening is the "span."

The level at which the curve of the arch commences is the "springing line." The vertical distance between the springing line and the highest point in the soffit constitutes the "rise." The lowermost voussoirs rest upon "imposts," the upper surfaces of which, called "skewbacks," should radiate like the voussoir joints from the centre of the arch.

Where there are a series of arches, the side supports of each intermediate arch are called "piers," and the end supports of the whole series, "abutments."

The "spandril" is the space included between the horizontal line through the crown, the vertical line through the summit of the skewback, and the curved line of the extrados. [*See* Plate 21(*a*.)]

Classification.—Arches may be classified, according as they are described or struck from one, two, three or more centres.

"One centre arches."—[*See* Plate 21 (*b*) (*c*) (*d*).] When the centre line is on the springing line the arch is "semi-circular."

A "segmental" arch has its centre below the springing line. For a given span there is an unlimited number of such arches. It is necessary, therefore, to completely define the arch, to state the rise, or the number of degrees in the angle subtending the arc.

A "horse-shoe arch has its centre above the springing line.

"Two centre arches."—[*See* Plate 21 (*e*), (*f*), (*g*).)]

"Lancet" arches have their centres at each end of the span.

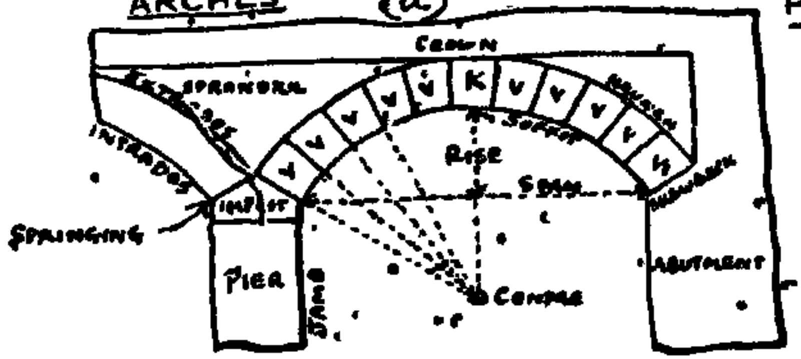
"Obtuse" or "Drop" arches have their centres within the span.

"Arches with more than two centres."—[*See* Plate 2 (*h*), (*j*), (*k*).]—What is sometimes called an "*elliptical*" *arch* is described from three centres, but as no part of the curve of an ellipse is circular, such an arch is not truly "elliptical."

ARCHES

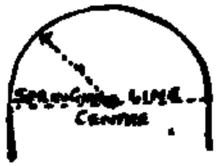
PLATE 21.

(a)



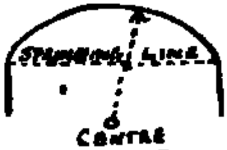
V = VOUSSOIRS K = KEYSTONE

(b)



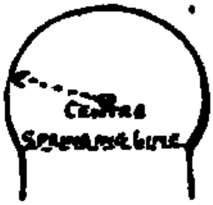
SEMICIRCULAR ARCH

(c)



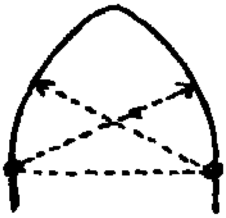
SEGMENTAL ARCH

(d)



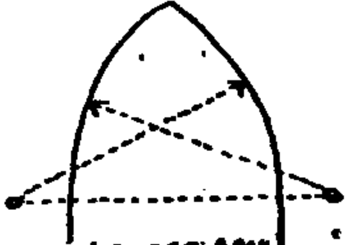
HORSE-SHOE ARCH

(e)



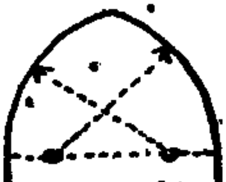
EQUILATERAL ARCH

(f)



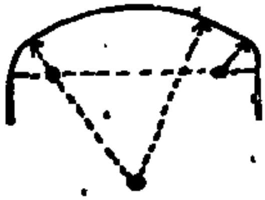
LANCET ARCH

(g)



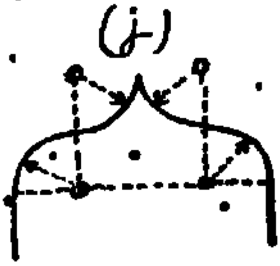
OBTUSE ARCH

(h)



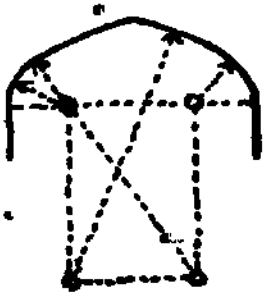
ELLIPTICAL ARCH

(j)



OGEE ARCH

(k)



TUDOR ARCH

The "Ogee" arch is struck from four centres, two above, and two below the curve.

A "Tudor" arch is struck from four centres, all four being below the curve.

A "Straight" or "Flat" arch has its soffit or intrados horizontal. The joints of the voussoirs radiate from a centre found by describing an equilateral triangle on and below the soffit, the apex of the triangle being the centre. (*See* Plate 22.)

"Relieving" or "Discharging" arches are built over lintels and other parts which it is desired to relieve of the superincumbent weight. (*See* Plate 22.)

"Rough" arches consist of ordinary bricks laid on edge. Owing to their unsuitable shape, the joints on the extrados are much wider than those on the intrados and for this reason such arches are turned in half brick rings. (*See* Plate 22.)

"Axed" arches or "rough cut" arches consist of bricks set on edge and having their sides roughly cut to the required radius.

"Gauged arches" consist of bricks first cut, and then accurately rubbed to the necessary shape, so that their sides radiate truly from the centre.

Inverted arches are used for distributing the pressure of piers over as great an area as possible. They have their centres above and their crowns below the springing. (*See* Plate 22.)

"Circular drains" may be constructed in brickwork when pipes are not available. Plate 22 shows a drain constructed of two half brick rings.

"Covered drain."—Another form of brick drain consisting of a semi-circular inverted arch covered with a flat stone is shown in Plate 22.

"Egg-shaped sewers."—The proportions of such sewers vary according to circumstances, but in all cases the invert should have a quick curve of radius not exceeding 9" and the crown should be a semi-circle (Plate 22).

Masonry.—Many of the terms explained under "brickwork" are equally applicable to masonry (stone work). Systematic bond is more difficult to arrange in masonry, owing to the want of uniformity of size and shape of the stones used.

Except in "*ashlar*" work no general rules can be laid down.

Two methods however may be referred to:

"Dog tooth" bond consists of headers overlapping each other from opposite faces of the wall at regular intervals. (*See* Plate 23.)

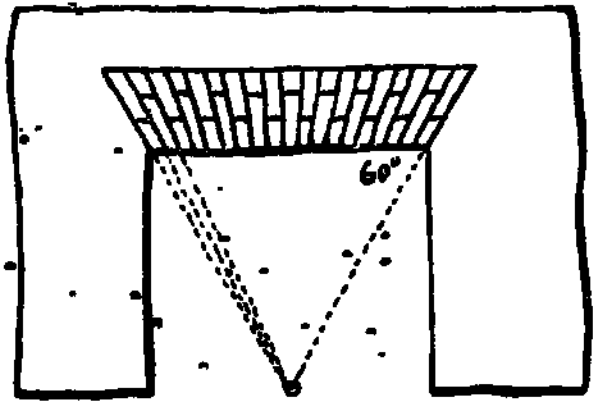
"Through bond" consists of headers which run right through the wall and appear on both faces. (*See* Plate 23.)

Masonry walling may be divided into two main classes, viz., "*rubble*" and "*ashlar*" work.

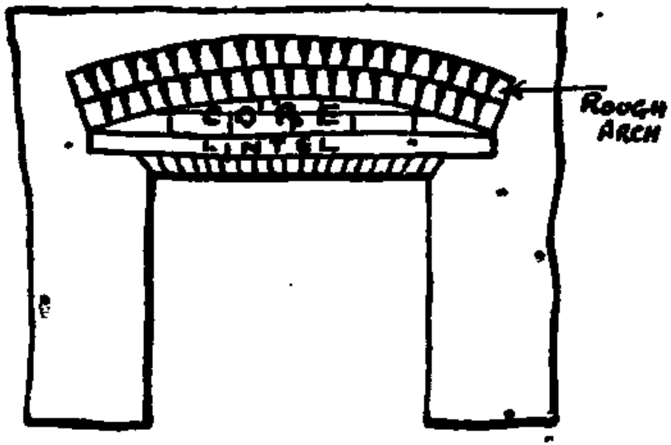
Each of these again admits of several subdivisions, so that the two classes gradually merge into each other.

Broadly speaking, the distinction between rubble and ashlar work lies in the fact that the former is done with stones dressed by the hammer only and has coarse joints, while ashlar work has the stones dressed with the chisel and is fine jointed. "*Random rubble*"

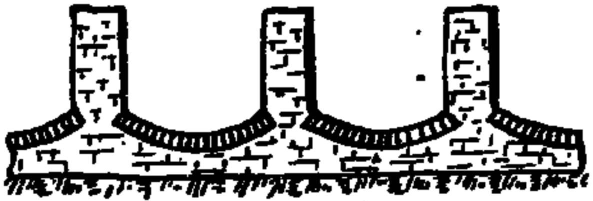
PLATE 22.



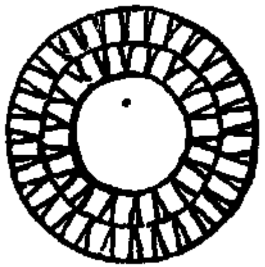
FLAT ARCH



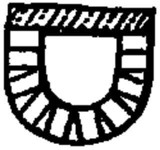
RELIEVING ARCH



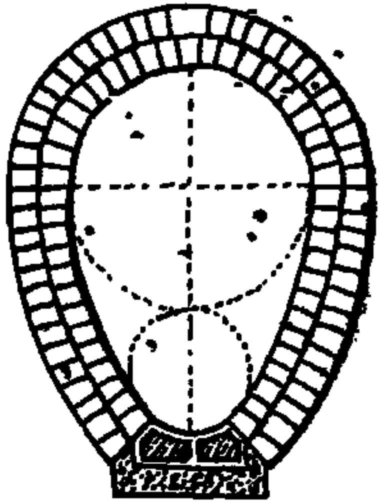
INVERTED ARCHES



CIRCULAR DRAIN



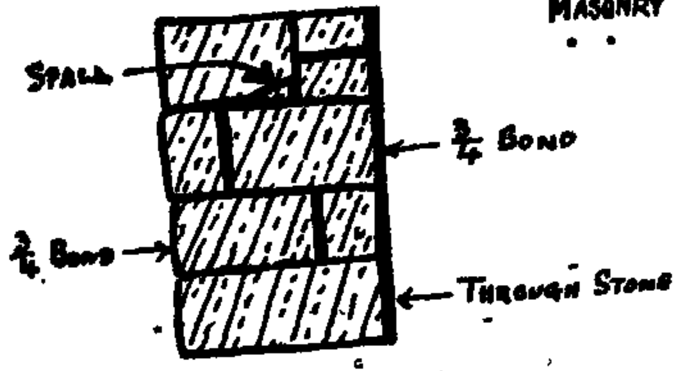
COVERED DRAIN.



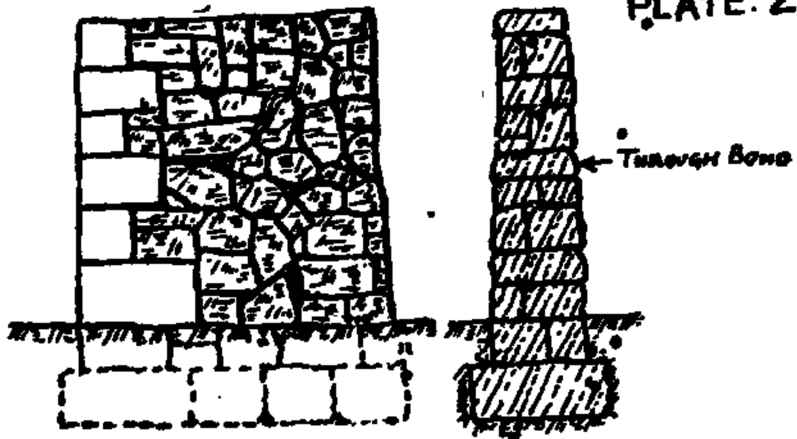
EGG-SHAPED SEWER

PLATE. 23.

MASONRY

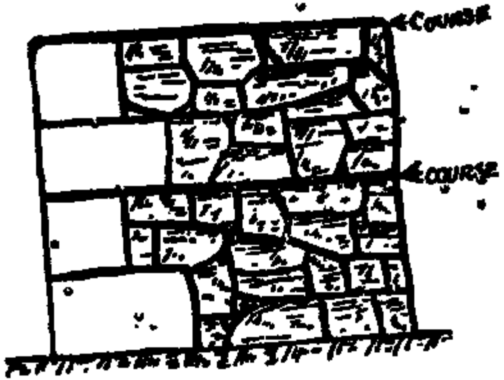


Bond in Masonry

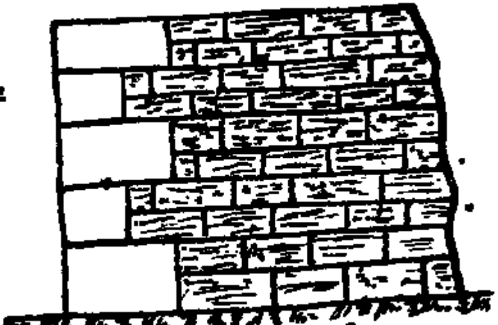


Section

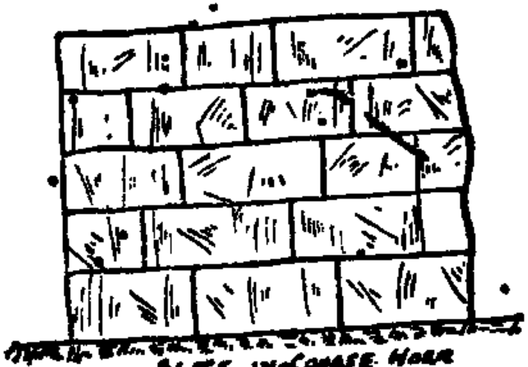
Uncoursed Random Rubble.



Coursed Random Rubble



Regular Coursed Rubble



Block-in-Course Work

is the roughest kind of rubble work. It consists of rough stones used without any dressing beyond the occasional removal of inconvenient projections. The mason picks the stones at random from his heap and works them into as perfect bond as possible filling the cavities with small stones.

Random rubble is of two kinds, "uncoursed" and "coursed." (*See* Plate 23.)

"**Regular coursed rubble**" (*see* Plate 23) have the course lines maintained throughout. Where the stones are large and heavy, as in the case of retaining walls and quays, this kind of work is known as "Block-in-Course" or "Hammer-dressed Ashlar." (*See* Plate 23.)

(Note the distinction between "Block-in-Course" and "Blocking Course," the latter being the topmost course surmounting a cornice.) "Ashlar work" (Plate 24) is divided into two divisions—"Irregular Coursed" and "Regular coursed."

Irregular coursed has the courses of varying height and the stones of varying lengths.

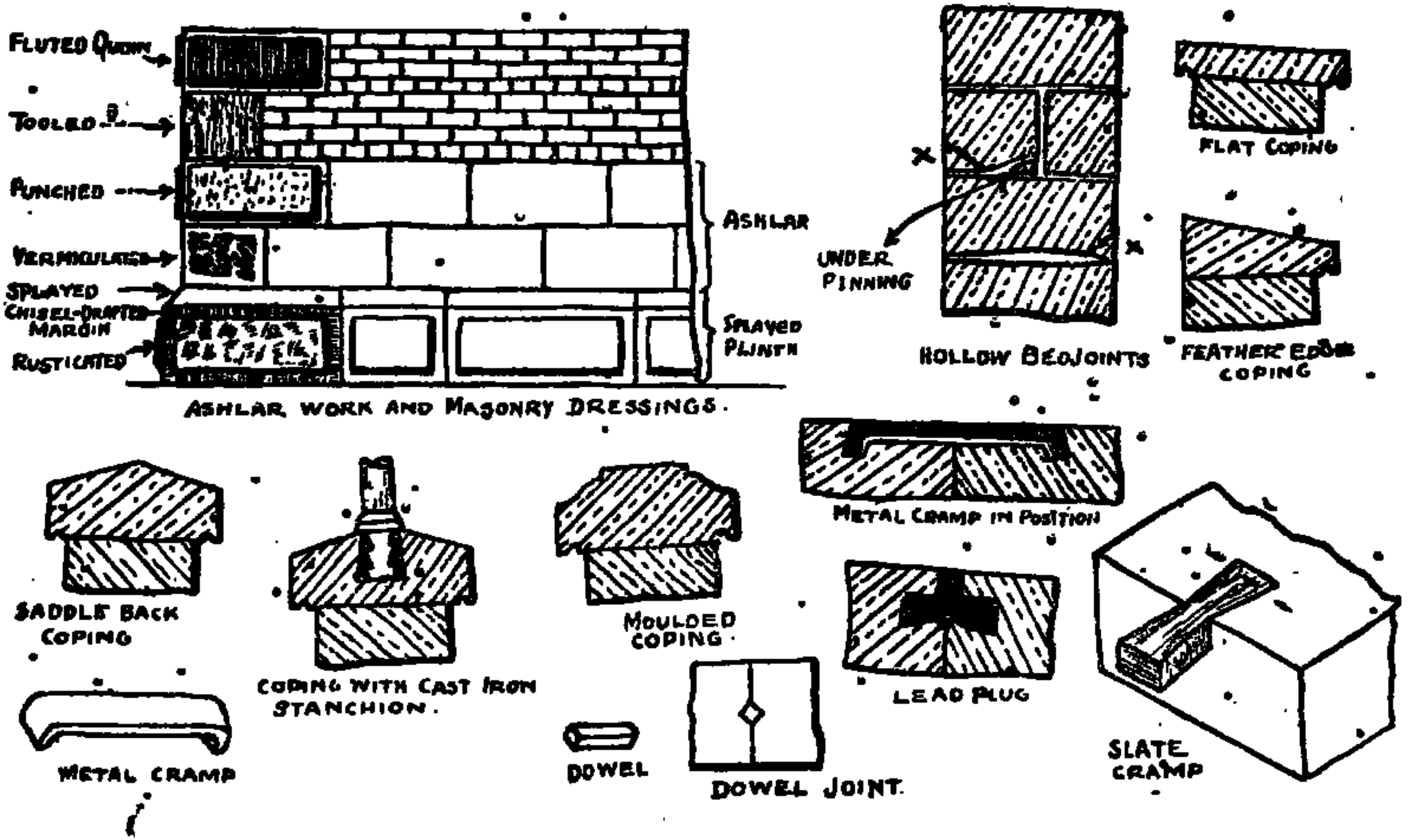
Regular coursed work has each course of equal height and the stones laid alternately as headers and stretchers. The joints in ashlar work should not exceed $\frac{1}{8}''$. Round the edge of each stone there should be a "drafted margin" to ensure accurate setting. (Plate 24.)

The softer kinds of building stone are in *good proportions* if the breadth and depth are equal, and the length about three times the breadth. The length of the harder varieties may be greater. Hollow bedding should be avoided. The weight of the upper masonry bearing on the outer edges of the stone causes fracture, as illustrated at xx in Plate 24.

The face of each stone is generally worked smooth, but it is sometimes left rough, or rusticated as shown in the plinth. (Plate 24.)

Various methods of "dressing" the quoins are shown in Plate 24. Stone copings are shown in Plate 24. Where greater security is essential than can be obtained by the adhesion of mortar, metal-fastenings may be used. "Metal cramps" are made in the form shown in Plate 24. They are let into a groove which is then run with molten lead (Plate 24). Owing to galvanic action set up between iron and lead the cramp is often made of copper or bronze. Another objection to lead is that it contracts on cooling and has to be "caulked" with a caulking chisel in order to fill up the cavity. Portland cement, or a mixture of sulphur and sand, are frequently used as substitutes. "Lead plugs" (Plate 24) are formed by pouring molten lead into dovetail cavities. The bottom of the cavities slope downwards in order that it may be thoroughly filled. "Dowels" consist of metal, or slate or hard stone, and are rectangular, diamond-shaped and circular, or tapering in shape. They fit into sockets cut to receive them. (Plate 24.)

PLATE. 24.


FLUTED QUOIN
TOOLED
PUNCHED
VERMICULATED
SPLAYED
CHISEL-DRAFTED MARGIN
RUSTICATED
ASHLAR
SPLAYED PLINTH
ASHLAR WORK AND MASONRY DRESSINGS.
X
X
UNDER PINNING
HOLLOW BEDJOINTS
FLAT COPING
FEATHER EDGE COPING
METAL CRAMP IN POSITION
SADDLE BACK COPING
COPING WITH CAST IRON STANCHION.
MOULDED COPING
LEAD PLUG
SLATE CRAMP
METAL CRAMP
DOWEL
DOWEL JOINT.

CHAPTER VII.

Carpentry and Joinery, Centering, Doors and Windows.

Joiners' work is concerned with internal fittings in a building, as distinguished from the carpenter's work, whose province in a building is "structural." The carpenter uses timber in pieces of large size, the dressing of which is not so essential as in the case of joinery.

Definitions.—An *Arris* is the sharp edge of a piece of timber. "*Chamfering*" consists in taking the edge off the arris (*see* Plate 25*a*). When the chamfer is sloped or curved at any point into the square edge of the arris, it is called a "*stopped chamfer.*" *A splay* is a wide chamfer. *Housing* is letting the whole end of a board or other piece of timber into another piece (Plate 25*b*). In framing (fitting together by suitable joints, separate pieces of timber, so as to form a single piece of considerable surface), the vertical members are called *styles*, the horizontal members *rails*, and the spaces enclosed by these "panels."

Mouldings.—A nosing is formed by rounding off the edge of a step or projecting board (Plate 25*c*). When the nosing is large it is called a *Torus* and is then used with a *Fillet* or narrow strip placed above the *Torus* (Plate 25*d*).

An Ovolo is half a nosing and is also surmounted by a fillet (Plate 25*e*).

Double Ovolo mouldings are often used for window sash bars (Plate 25*f*).

A Bolection Moulding is one which projects beyond the plane of the framework of a door (Plate 25*g*).

Beads are mouldings of small girth. The indentation at the side of a bead is called a *Quirk* (Plate 25*h*).

A staff, angle, or Return bead is formed along an edge for the purpose of improving the appearance. It is also less liable to injury than the sharp edge of an arris. (Plate 25*j*).

Reedings are a series of parallel beads arranged close to each other.

Joints. Lapping is the simplest way of joining two pieces of timber. The end of one piece is made to overlap the end of the other piece, and they are secured by straps or bolts. (Plate 25*k*.)

Butting and Fishing.—Plate 25*l* shows two timber beams, having their ends truly squared and butting against one another. They are secured by means of pieces of iron, called fish plates, through which bolts are passed.

In Scarfing or Splicing the joint is formed within the limits of the thickest of the pieces to be joined, by means of corresponding projections and indents, which are fitted together and the pieces secured by wedges, keys, bolts or straps, with or without fish plates (Plates 25*m*, *n*, *p*.)

Plain halving (suitable for joints in wall plates) (Plate 26*a*.)

Dovetail-halving, also used for joints in wall plates. (Plate 26*b*.)

PLATE 25

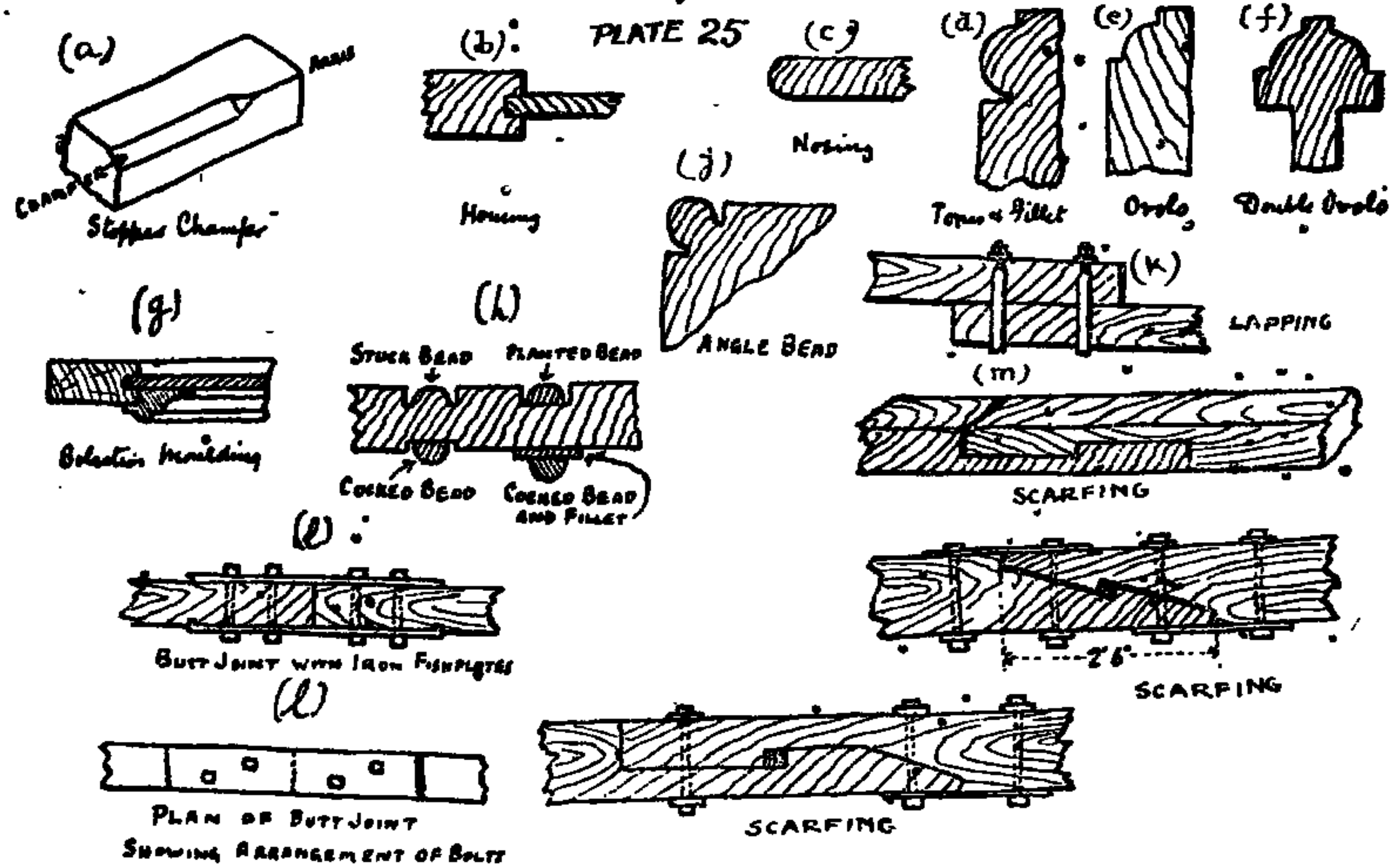
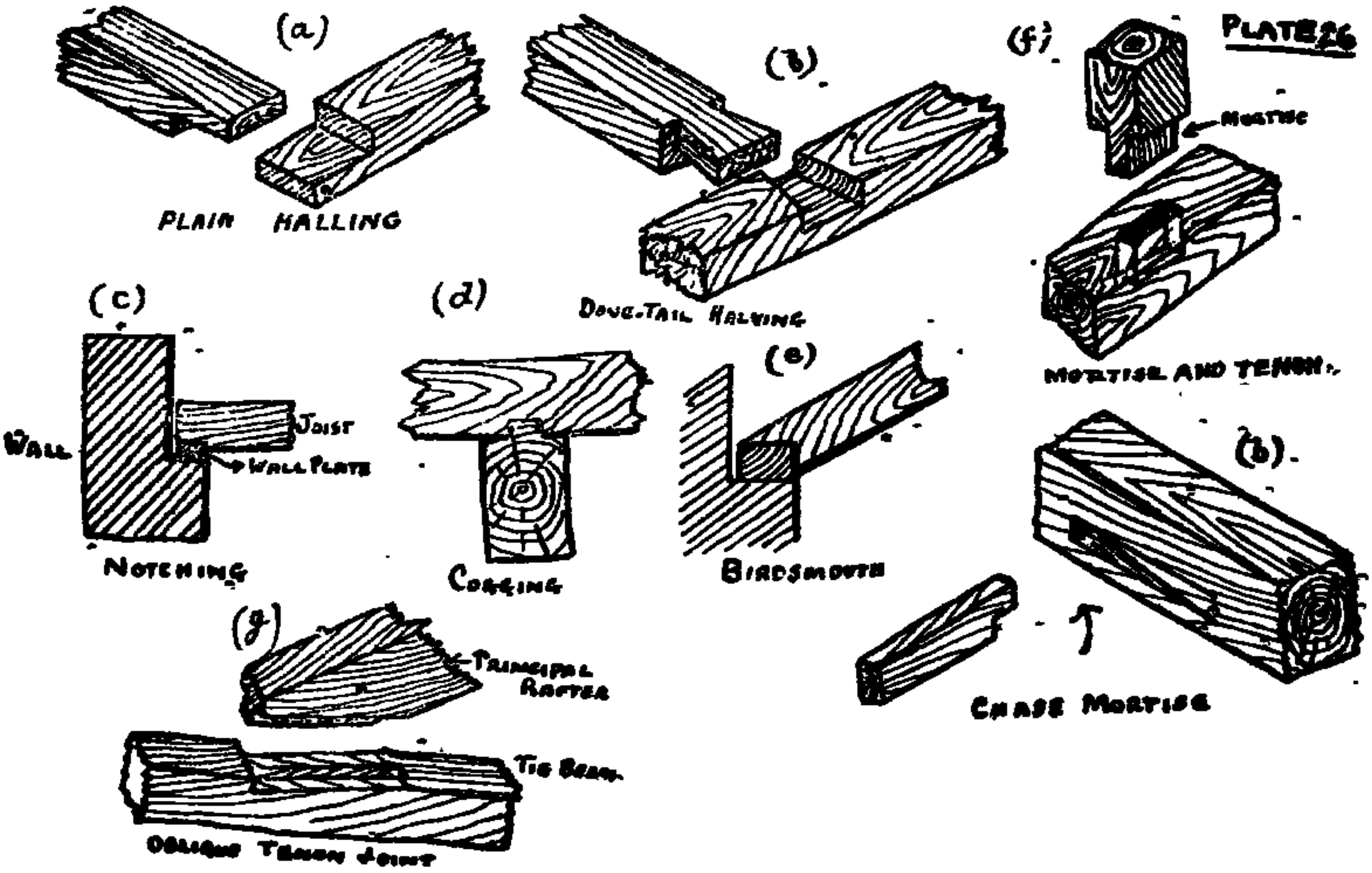

(a)
Arris
Chamfer
Stopped Chamfer
(b)
Housing
(c)
Nosing
(d)
Torus & Fillet
(e)
Ovolo
(f)
Double Ovolo
(g)
Bolection Moulding
(h)
Stuck Bead
Planted Bead
Cocked Bead
Cocked Bead and Fillet
(j)
Angle Bead
(k)
Lapping
(m)
Scarfing
(l)
Butt Joint with Iron Fishplates
(l)
Plan of Butt Joint
Showing Arrangement of Bolts
2' 6"
Scarfing
Scarfing

PLATE 26


(a)
PLAIN HALLING
(b)
DOVE-TAIL HALVING
(f)
MORTISE
MORTISE AND TENON.
(c)
WALL
JOIST
WALL PLATE
NOTCHING
(d)
COGGING
(e)
BIRDSMOUTH
(b)
CHASE MORTISE
(g)
PRINCIPAL RAFTER
TIE BEAM
OBLIQUE TENON JOINT

Notching. (Plate 26c.) *Cogging* is a modification of notching. Cogging has an advantage over notching in that the joist is not weakened at the point of support. (Plate 26d.)

Birdsmouth is the term applied to an angular notch. (Plate 26e.)

Mortise and Tenon.—Joints are frequently used in framework. The thickness of the tenon is generally about one-third that of the pieces on which it is formed. The rectangular recess which receives the tenon is called the mortise. (Plate 26*f*.)

Oblique Tenons are used in cases where the pieces to be joined do not meet at right angles, as in the case of the foot of the principal rafter of a roof truss and tie beam. (Plate 26*g*.)

Chase Mortise.—When a post or rail has to be tenoned at each end into pieces which are already fixed a groove has to be cut leading to the mortise. (Plate 26*h*.)

Centering.

Wood centres (or centering) are temporary frames, built to support brick or stone arches during the process of building. They consist of *ribs* or pieces cut to the required curve, across which are nailed narrow battens or laggings. The ends of the ribs rest on *folding wedges* through which the weight of the arch is transmitted to the props. The object of the wedges is to allow the centering to be gradually lowered, so that the arch may not be strained by any sudden settlement. Plate 27 illustrate centerings suitable for small and large arches respectively.

Doors and Windows.

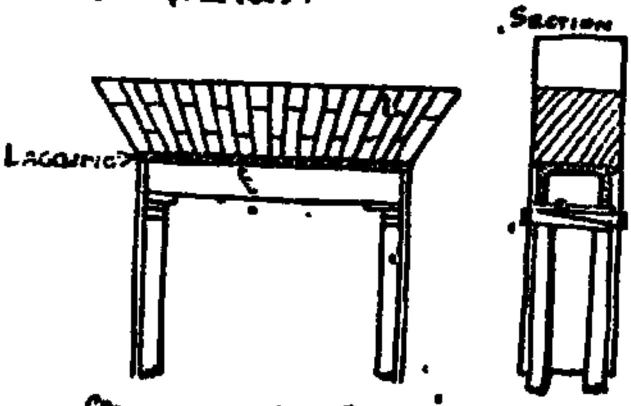
Doors.—No rules can be laid down for the proportions of doors; 6′ 6″ is ample height for internal doors. Bedroom doors should not be less than 2′ 6″ wide, sitting room doors 3′ or 3′ 6″ wide. Width is more essential than height, as few men can touch 6′ 3″, whereas a narrow door is awkward for servants carrying trays and makes it difficult to move large pieces of furniture from one room to another. Single doors over 3′ 6″ wide should however be avoided. If it is necessary to have a wider opening it is better to have double doors, in which case the width of both doors should be at least 4′ 6″. Narrow double doors are objectionable. Persons entering and going out jostle one another, and to enter with a tray means throwing open both doors. External doors should never be less than 3′ 6″ wide, for the sake of appearance as well as for utility. A common rule for size of doors, in India, is height = width + 3′ to 3½′.

Types of doors.—Doors are described according to their construction as follows:—

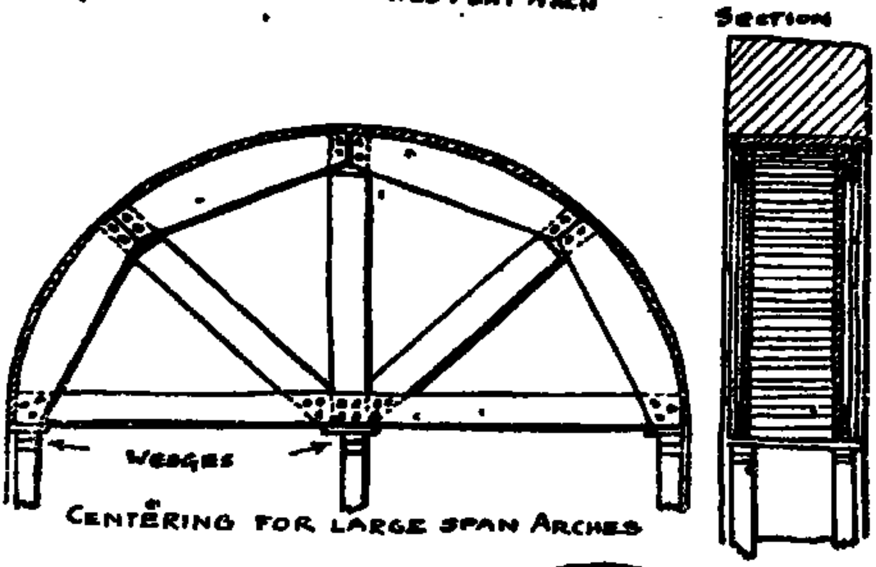
Ledged and braced.
Framed, ledged and braced.
Panelled.
Panelled and glazed.
Venetianed.

A ledged and braced door consists of boarding ¾″ to 1″ thick, strengthened at the back by three cross ledges and two braces of

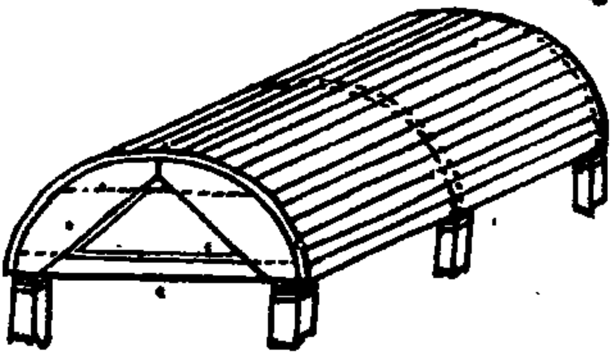
PLATE 27.



Centering for Small Flat Arch



Centering for Large Span Arches



Centering for Continuous Arch of Great Length
Suitable for Brick Sewer &c.

similar thickness. The braces should always slope upwards from the side on which the door is hung. [*See* Plate 28 (*a*).]

Framed, ledged and braced doors are of stronger construction. The frame, 1½" or 2" thick, consists of two side stiles and a top rail tenoned into them. On the outside is boarding of half the thickness, and on the inside are a lock rail, bottom rail, and two diagonal braces, also half the thickness. These are all tenoned into the frame. The boarding is tongued into the stiles and top rails, and in addition is nailed to the braces and other rails. [*See* Plate 28 (*b*).] Both these types of door are hung on the door frame ("chokut") either by strap or butt hinges. *A panelled door* may have one or more panels. A single panel is effective in appearance, and provided its stiles and rails are at least 2" thick, its panel correspondingly thick, will remain straight and true. Two-panelled doors are best when the width does not exceed 3', nor the height 6' 6". Six panels are usually found in doors over 6' 6" high. [*See* Plate 28 (*c*) and (*d*).]

Panelled and glazed doors.—As a rule only the portion above the lock rail is glazed.

In Venetian doors the panels are substituted by venetians. The blades of the venetians should be 3½" wide, ⅜" thick and should overlap about half their width. The blades are secured to a moulded stanchion by brass hinges. The frame of each shutter is rebated *outside* on side and bottom rails, and *inside* on the top rail. The ends of the blades are rounded off in the centre to ⅜" diameter and ¼" inch long, to fit into holes in the rebated portion of the frame. [*See* Plate 29).]

Framing of doors.—The different parts of a door are framed together with mortise and tenon joints (Plate 30). The top rail has a haunched tenon [Plate 30 (*b*)]. Intermediate rails have single tenons [Plate 30 (*c*)]. The bottom rails have double tenons, usually haunched [Plate 30 (*d*)]. Lock rails have double haunched tenons on the hanging side [Plate 30 (*e*)] and a pair of double haunched tenons on the striking side [Plate 30 (*f*)]. The reason for the four tenons of the latter is to allow space for the insertion of a mortise lock.

Thickness of doors.—Doors are from 1½" to 2½" thick according to size, kind of wood used, etc.

Positions of lock rail.—The proportions of doors are often spoilt by having the lock rail too low. The best height is 3' from the floor to the centre of the rail.

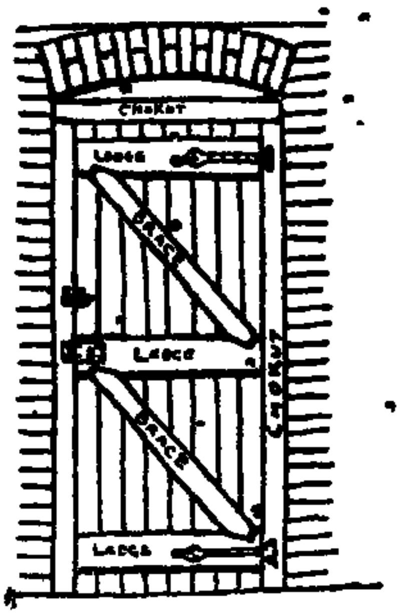
Position of doors.—Doors should always open so as to conceal the room as much as possible. A "right-handed door" is one that opens inwards to the right. "Left-handed doors" open inwards to the left. The "chokuts" are fixed to the walls either by holdfasts (Plate 31) or by coach screws driven through the chokut into wooden wedges or plugs. The latter are built into the wall at intervals of 2'. The top members of the chokut are sometimes projected into the wall on each side of the door opening. Doors between bed rooms or between bed and bath room should be panelled.

Windows.—There are no hard and fast rules for the proportions of windows. In dwelling houses the area of glass should be equal to one-tenth the superficial area of the room. In schools, offices,

PLATE 28.

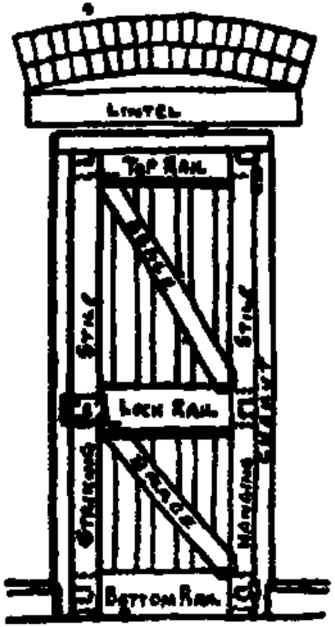
DOORS.

(a)



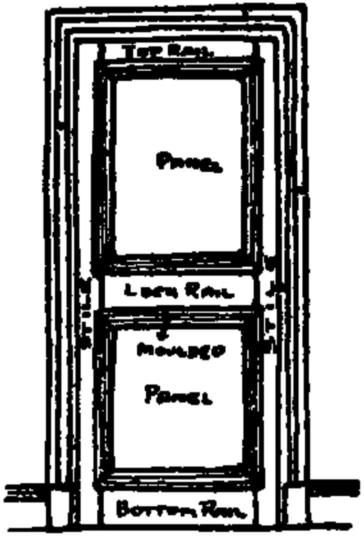
LEDGED AND BRACED DOOR
INTERNAL VIEW

(b)



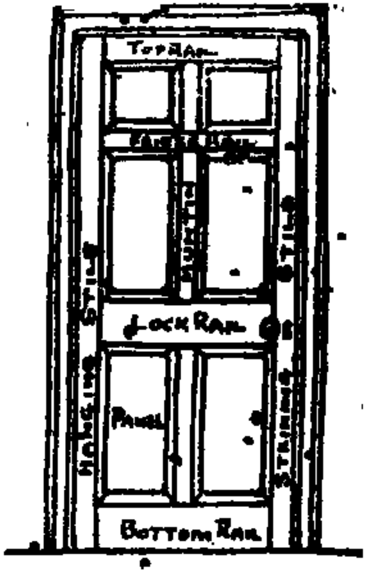
FRAMED LEDGED
AND BRACED DOOR
INTERNAL VIEW

(c)



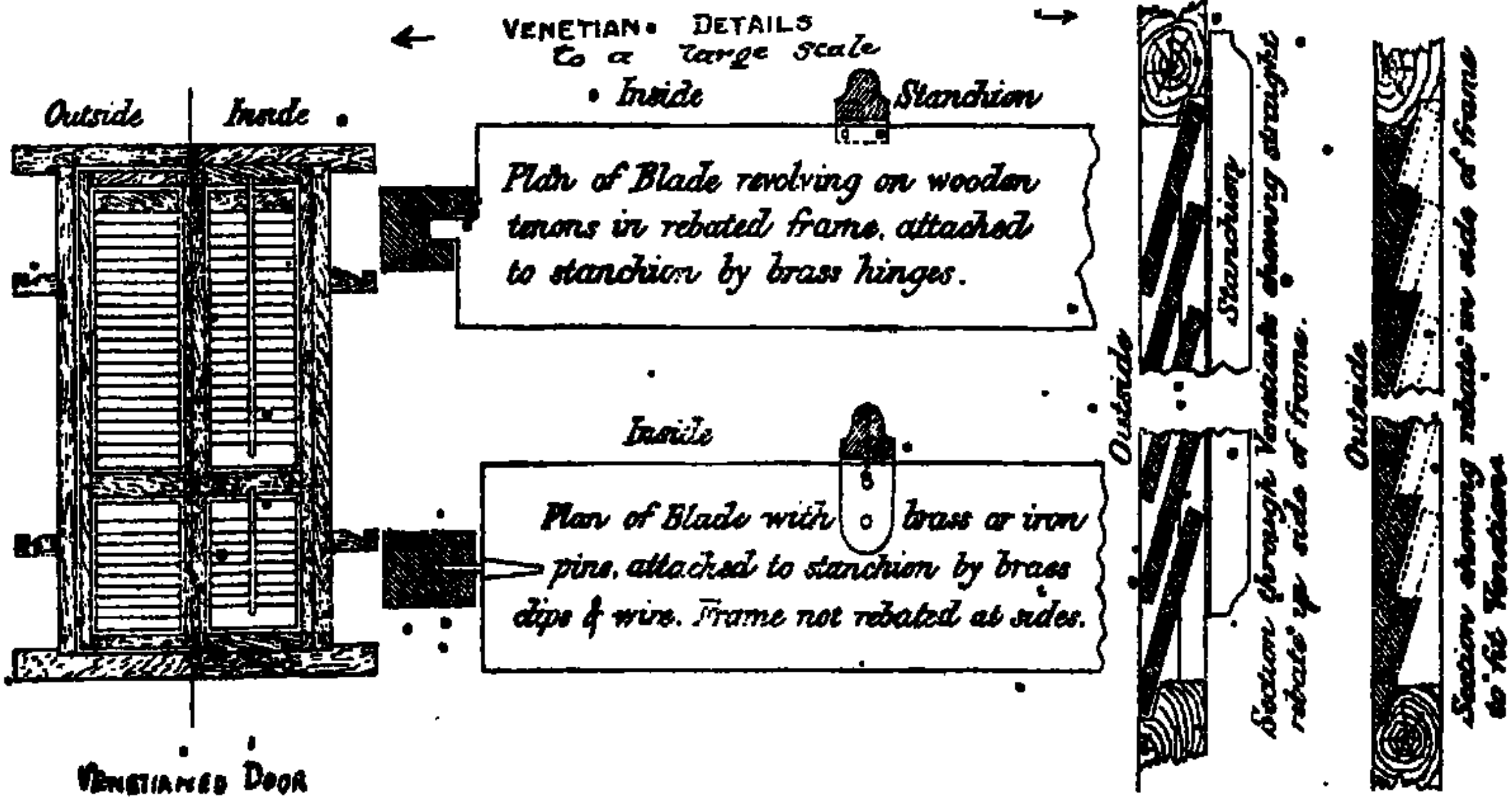
TWO-PANELLED
SINGLE DOOR

(d)



SIX-PANELLED
SINGLE DOOR

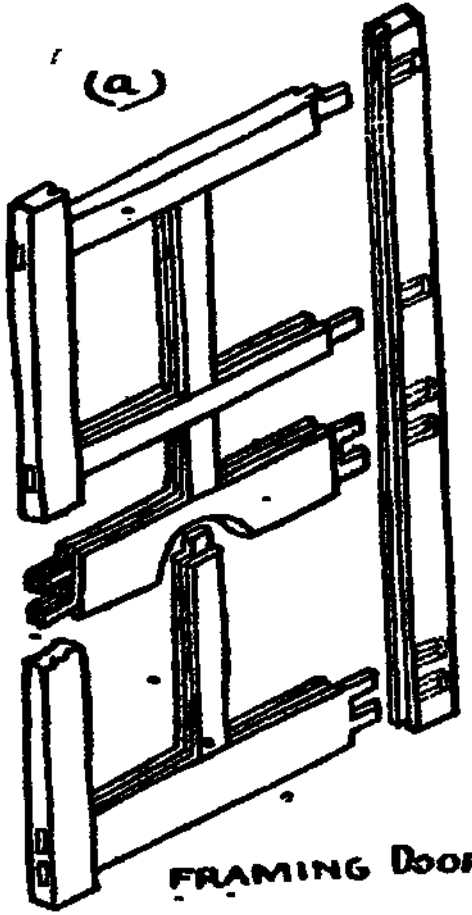
PLATE. 29.


VENETIAN DETAILS
to a large scale
Outside
Inside
Inside
Stanchion
Plan of Blade revolving on wooden tenons in rebated frame, attached to stanchion by brass hinges.
Inside
Plan of Blade with brass or iron pins, attached to stanchion by brass clips & wire. Frame not rebated at sides.
Outside
Stanchion
Section through Venetians showing straight rebate up side of frame.
Outside
Section showing rebate in side of frame to fit Venetians

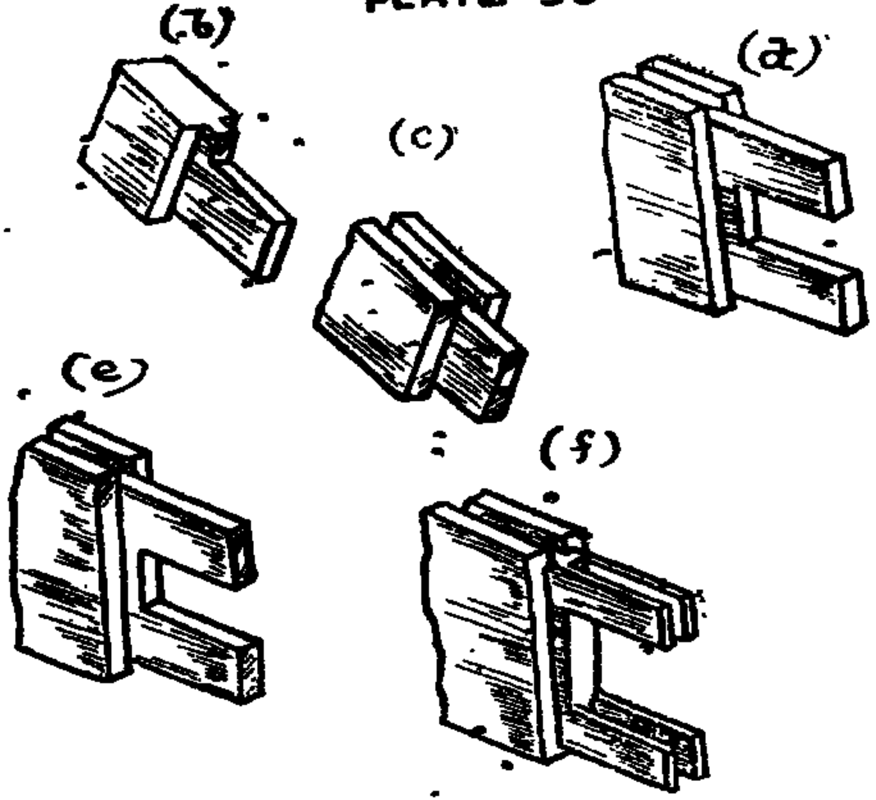
VENETIANED DOOR

DETAILS TO LARGE SCALE

PLATE 30

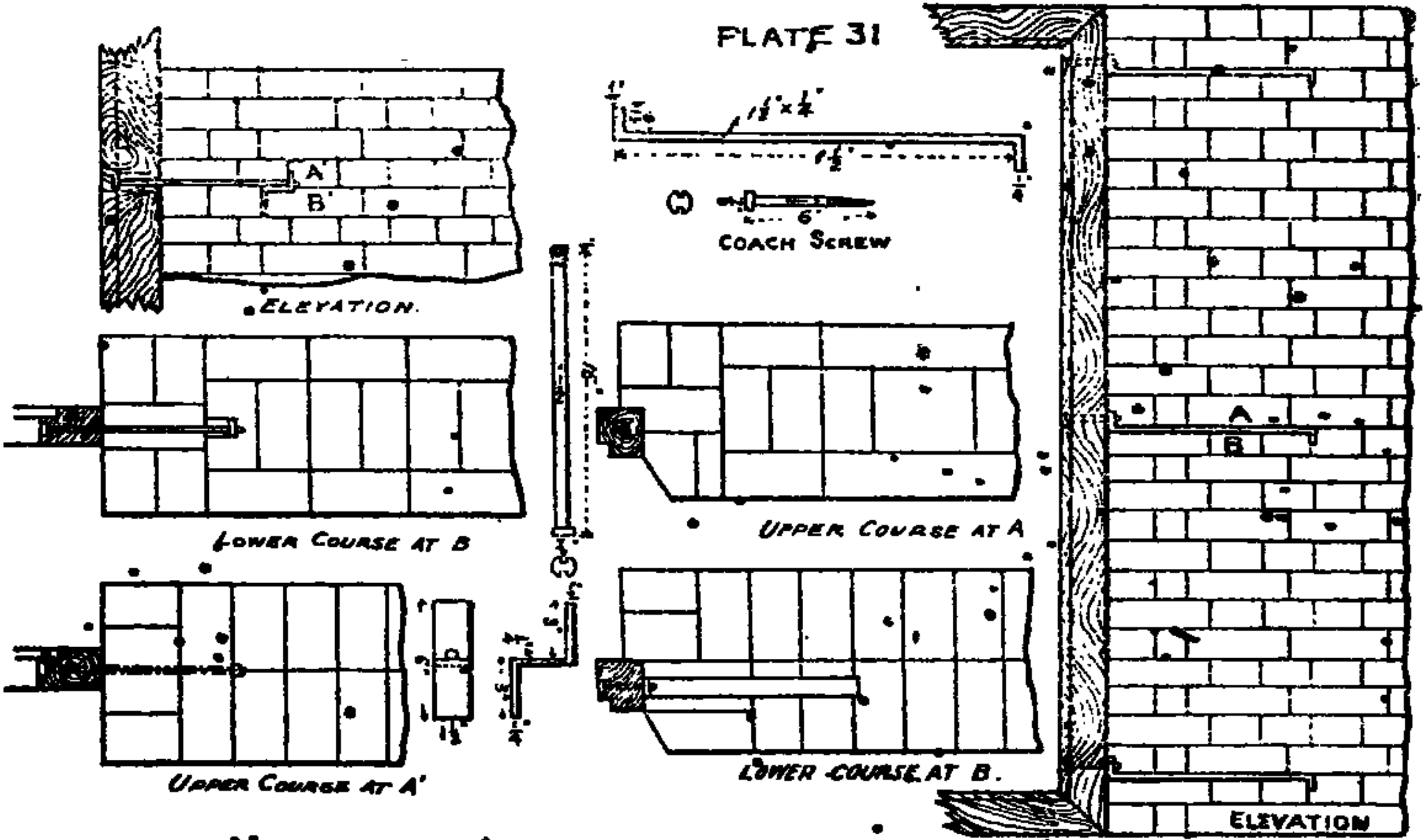


FRAMING DOORS



TENONS USED IN DOOR FRAMES.

PLATE 31



METHOD OF FIXING DOOR AND WINDOW FRAMES (CHOUKUTS)
TO WALLS.

laboratories, etc., one can hardly have too much light. The area of glass in these should be equal to one-fifth the superficial area.

French or Casement window.—Plate 32*a* is hinged vertically in two leaves and may be hung so as to open either inwards or outwards like a door, the latter arrangement being preferable in exposed situations. It has a solid frame recessed into the brick work. To this the sash stiles are hung and a weather-tight joint formed by a semi-circular projection on the stile fitting into a semicircular groove on the frame. Plate 32*b* and *c* make this clear and also show the rebated joint of the meeting rails, protected on the outside by a cocked bead and fillet and concealed on the inside by a quirked bead.

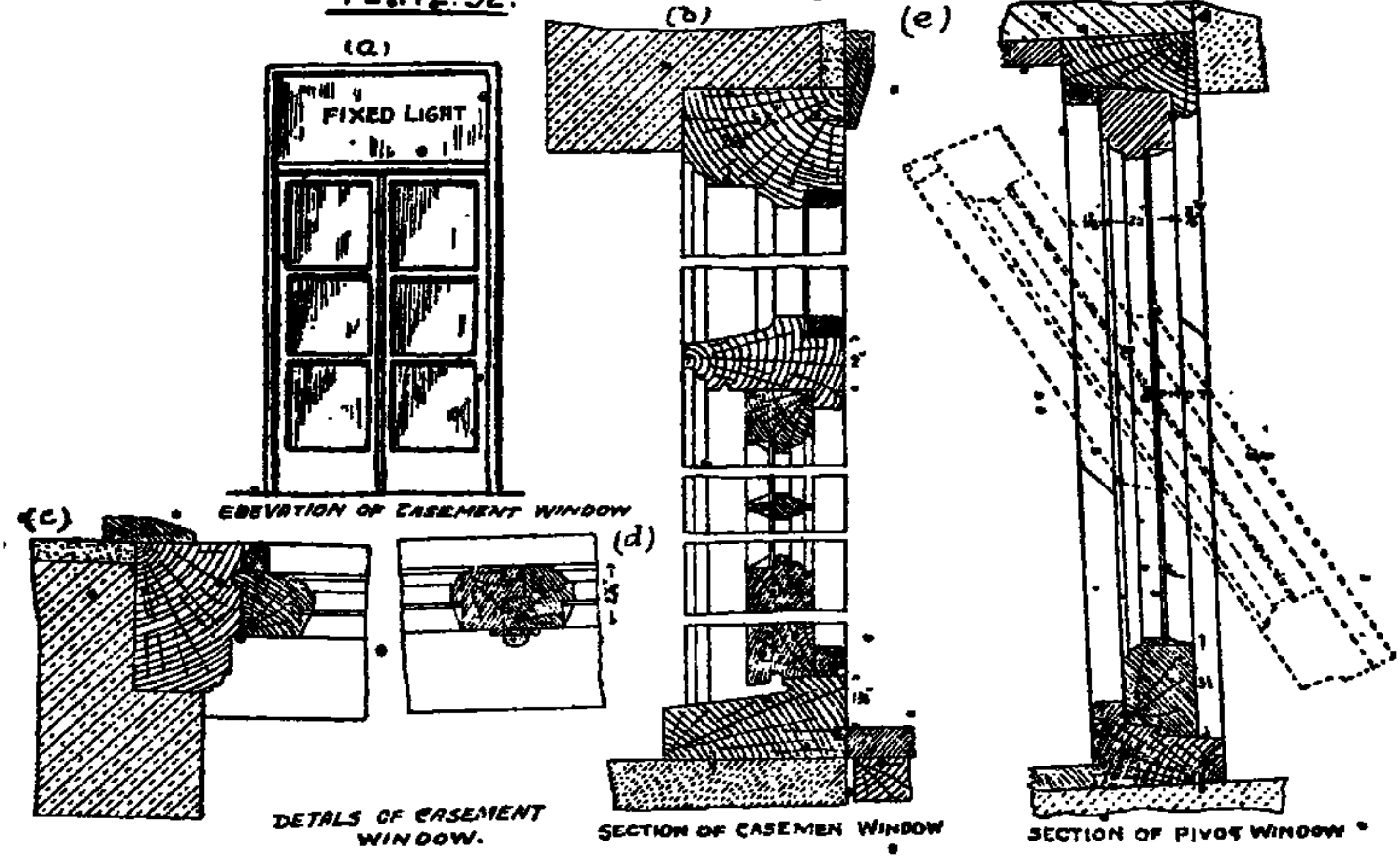
A vertical section is shown in Plate 32 *b*. The window is in two parts, the upper *fixed light* being separated from the casement by a transom.

The glazing of the fixed light is done with beads secured directly to the frame (chokut). The transom has its upper surface weathered and its inside throated.

The casement proper is moulded on the inside and rebated for glazing on the outside. One of the two horizontal sash bars is shown in section in Plate 32*c*. One method of making the joint between the lower rail and the sill weather-tight is shown in the section. (Plate 32 *b*.)

A Pivot Window consists of a single sash hung to a solid frame by means of two pivots attached to the stiles and fitting into sockets in the frame. The pivots should be placed slightly above the centre line in order that the window may have a tendency to close itself. The lower half should swing outwards to prevent rain entering over the top. Fig. 32*e* is a vertical section of a pivot window showing the window closed, and open (dotted lines). The upper half of the outside beads are fixed to the sash and move with it, while the lower half of the inside bead and the upper half of the outside bead are nailed to the frame or chokut.

PLATE. 32.



EBEVATION OF CASEMENT WINDOW

DETALS OF CASEMENT WINDOW.

SECTION OF CASEMEN WINDOW

SECTION OF PIVOT WINDOW

CHAPTER VIII.

Floors and Ceilings, Roofs and Roof Coverings.

The types of floors generally employed in India are as follows :—

Wooden floors usually employed in hill stations only, owing to the destructive agencies at work on timber in the plains.

Brick-on-edge floors.—This a common type for a ground floor. The surface is prepared by excavating to the depth necessary, carefully levelling the surface, and finally ramming and consolidating. On the bed thus prepared a layer of dry sand 3" deep is spread over which is laid a course (or two) of brick in mortar laid flat. The brick on edge is then very carefully laid, either in parallel rows breaking bond, or herring-bone bond. The mortar joints should not exceed ⅜". Brick-on-edge floors are suitable for store rooms or godowns.

Tile or flat-brick flooring.—The bed is excavated and prepared as for brick-on-edge flooring. A layer of 6" of brick concrete is then laid and well rammed down. Over this is laid paving tiles (or bricks) set in mortar, so as to break joint. Care is necessary to insure a perfectly even and smooth floor being obtained. The joints should be rubbed and only the hardest and best bricks used The joints should not exceed $\frac{1}{16}$" in thickness. In damp localities and in places infested with white ants, a layer of pure dry sand 3" deep may be spread under the concrete. Flat brick floors are sometimes provided in unimportant residential buildings and offices.

Terraced floors consist of 6" of concrete laid on a surface prepared as for brick-on-edge flooring and well rammed. To obtain a smooth surface, the concrete is liberally sprinkled with water while the final beating is in progress. The water should contain *gur* and bael fruit in the proportion of 3½ seers *gur* to 2 seers bael fruit, to about half a barrel of water. When the heating has been completed the surface is softened with pure water, and the mortar which has risen to the surface by beating is smoothed with the face of the trowel. The floor should be kept thoroughly damp for about three weeks after it is finished. Terraced floors do not wear well and are not recommended.

Stone flag floors.—The earth filling should be levelled, watered and well rammed until completely consolidated. For inner floors the surfaces should be perfectly level, but in verandahs an outward slope of one in forty must be given to the completed floor. Six inches of concrete is now laid and thoroughly rammed. The stone slabs should be laid over concrete with joints not exceeding ⅛", and should be evenly and firmly bedded flush in mortar, no hollows being left. The stones, as far as possible, should be of one size, but not less than 14" by 14". They should be from 1¼" to 1½" thick.

Patent stone flooring is much used for hospitals, or bathrooms, pavements, etc., owing to its durability and non-absorbent properties. It consists of Indian patent stone made with slag ballast obtained from the Indian Patent Stone Company, Calcutta. It is laid on four inches of concrete which has been rammed on a surface prepared as described for stone-flag floors. To lay the stone thin battens in frames are placed uniformly on the bed not more than 6' apart, and having a depth equal to that to which the stone is to be laid, say 1".

A mixture of Portland cement and slag is then prepared in the proportion of one to three. These are thoroughly mixed dry, after which water is added until the mixture is of the consistency of mortar. This mixture is then spread evenly between the battens on the concrete bed, the latter having first been thoroughly cleaned and wetted. The mixture is well beaten down with wooden mallets. More of the mixture is now spread on top of the beaten surface, and the straight edge drawn over the battens till a flat smooth surface is obtained. This surface is now rubbed and smoothed over with a trowel after which the floor is left undisturbed for 12 hours. The floor is then flooded with water and the surface of the floor kept under water for 10 days. One hundred square feet of flooring 1 inch thick requires 10 c. ft. of slag and 3½ c. ft. of cement (measured dry).

Fire-resisting floors.—In public buildings it is of the greatest importance to prevent the spread of fire, should one occur. Fire-resisting floors largely effect this prevention.

The materials composing such floors should be fire-resisting, or if liable to damage as in wrought or cast iron, must be protected by fire-resisting materials.

Wrought iron is liable to warp and twist under the action of great heat. It may be protected by terra cotta blocks or by plaster. Cast iron will crack and split, if greatly heated and then subjected to a stream of cold water.

Wood is sometimes protected by asbetos paints.

Brick and terra cotta are good resisters.

Concrete and plasters resist fairly well if largely formed of gypsum. Some types of fire-resisting floors have mild steel acting in the concrete as a reinforcing material.

When expanded metal is used as a reinforcement, the main beams are usually rolled steel joists, and the expanded metal (in section) forms ½ per cent. of the concrete forming the slab. Fig. 33 shows section of such a floor. The "form" or centering used to support the concrete and expanded metal during construction is also shown.

CEMENT CONCRETE FLOOR FIG. 33.

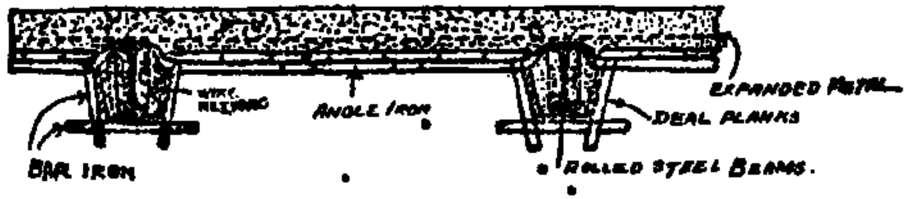
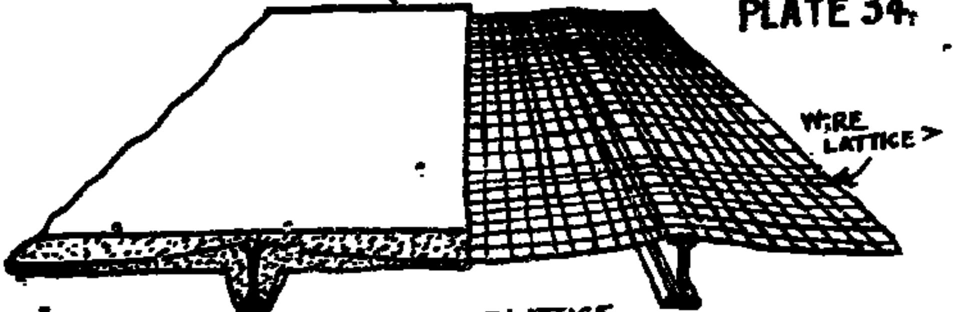


Plate 34*a* shows a fire-resisting floor in which the reinforcement consists of Johnson's steel wire lattice. With this kind of reinforcement cement concrete floors 3 to 6" thick can be constructed, with rolled steel joists, 7 to 10 feet apart, centre to centre, and will carry a safe working load of 1¼ cwt. per square foot.

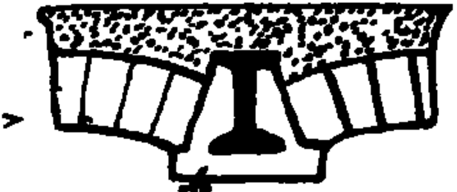
PLATE 34.

(a.)

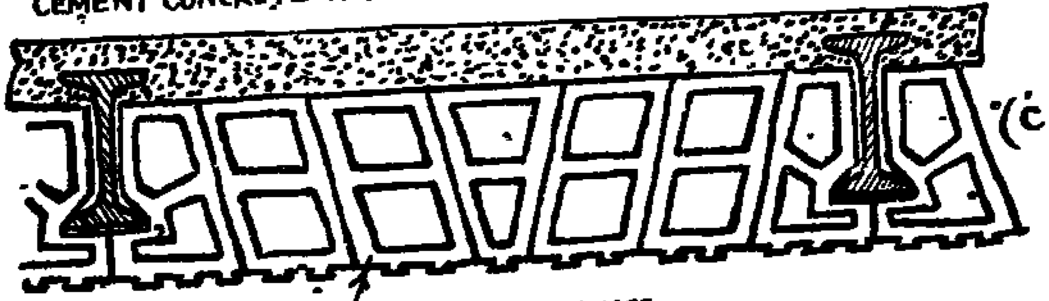


CEMENT CONCRETE WITH WIRELATTICE

CONCRETE ON BRICK ARCHES. (b).



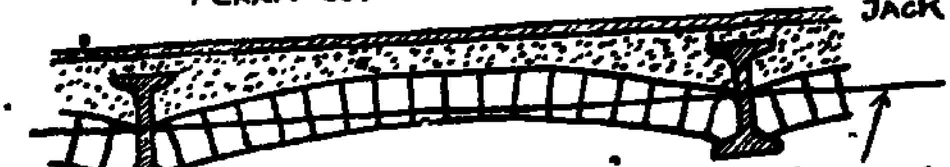
FIRE RESISTING BLOCKS.
9" LONG, MEAN THICKNESS 1½"



(c):

TERRA-COTTA BLOCKS.

JACK ARCH FLOOR.



(d).

TENSION ROD UNITING GIRDERS
AND PREVENTING THEIR YIELDING UNDER THRUST OF ARCHES

Plate 34*b* shows a floor in which the rolled steel beams are protected by fire-proof blocks, with brick arching between covered with concrete.

The blocks are made of fire clay, in lengths of 9" and have a minimum thickness of 1½".

They not only protect the rolled steel beams but act as skewbacks to the arches.

These brick arches are sometimes substituted with specially moulded hollow blocks of terra cotta fitted in between the joists to form a flat arch. The blocks are grooved on the under side to receive the ceiling plaster (*see* Plate 34*c*).

Jack arches and rolled steel joist floors are suitable for all floors above the ground floor. (Plate 34*d*.).

The arches may be of concrete or bricks, and are supported on rolled steel joists, the springing being either from the lower or the upper flanges.

The joists are placed parallel to each other at suitable distances apart, varying from 2' 6" to 4' according to circumstances. The rise of the arches varies from 4" to 8" according to the span adopted. The thickness at the crown is 6 inches if concrete is used.

The soffits are plastered and the top surfaces of the arches either finished off with cement plaster or stone paved as desired. The work should be kept damp while in progress. Portland cement concrete should carry safely 300 to 600 lbs. per sq. ft.

The thrust of the arches must be provided for either by sufficiently massive or buttressed walls, or by iron tie rods.

Ceilings.

Ceilings are of various kinds, such as plank, cloth, lath and plaster, plaster on expended metal, etc.

In plank ceilings. the planks may be fixed direct to the purlin rafters, leaving the main timber exposed to view.

In flat roofs of upper floors the main beams are varnished or painted and look well enough for unimportant buildings, but for better work, it is usual to add suspended ceilings by fastening the planks to steel or wood laths attached to bars spaced about one foot apart and clipped to the beams or suspended from them by hangers.

The ceilings may be panelled for appearance. All planks should be laid truly parallel or perpendicular to the walls, and be fixed with brass screws, the heading joints breaking joint. The ceiling should be finished with a wooden moulding running all round the walls.

Cloth ceilings are made of strong country cloth tied or screwed to wooden frames.

The frames are secured to tie beams of the trusses and to the wall plates. The cloth is whitewashed.

A wooden moulding should be run all round the walls.

Lath and plaster ceilings are made by attaching ceiling joists to the under side of tie beams, and placing split bamboos across them. The bamboos are then covered with plaster.

Plaster on expanded metal.—Ceiling bars of iron (called hangers) are fastened with clips to the bottom flanges of the rolled steel joists or tees, from which the expanded metal is suspended and covered with plaster.

Roofs and roof coverings.—The topmost external covering of a building (called the *Roof Covering*) is supported in various ways. The framework which supports the covering is called the *Roof truss* The term *Roof* is often indiscriminately applied alike to both the Roof covering and the Roof truss.

The span of a roof is the distance between the two walls upon which the roof trusses or beams rest. The span is generally measured clear of the supporting surfaces, the amount of which is called the *Bearing.*

The pitch of a roof is its inclination to the horizontal ; and may be stated either as the ratio of the rise to the span such as 1 to 4 or ¼, or by the number of degrees in the angles between the slope of the roof and the horizontal.

The pitch is determined by the nature of the roof-covering. Thus thatch which would easily allow rain water to penetrate it must be laid at a steep angle.

The following inclnations are recommended :—

> Thatch 45°, tiles 24° to 60°, corrugated iron 18° to 20°, slates 22° to 30°, boarding 26½°.

Roofs are covered with different materials, and there are many methods of constructing the supports, depending to a great extent upon the span, nature and importance of the building, the climate, etc.

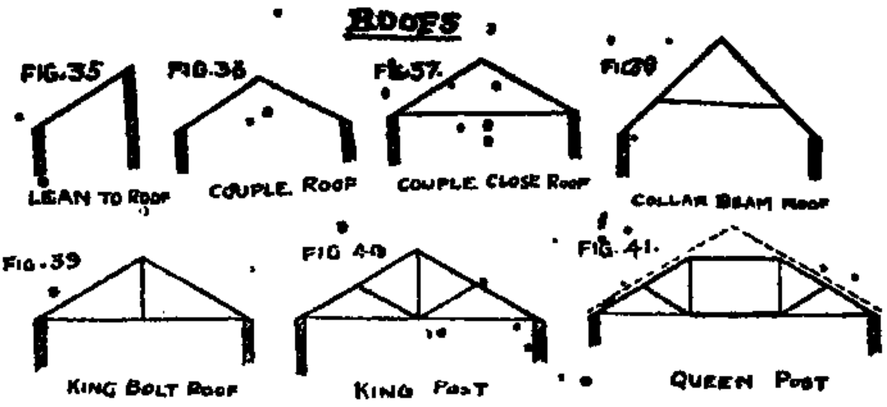
The supports may be of timber or iron. Roofs may be broadly classified under two main heads : Flat roofs and sloping roofs. The *flat roof* is the simplest, but can only be used for small spans, and is also liable to the objection that rain and snow falling on a flat surface are not easily thrown off and leakage is likely to occur.

The types commonly used are concrete, terraced roofs, jack arched roofs, and reinforced concrete roofs.

The more important types of *sloping roofs* used India are tile, corrugated iron, slate supported on trusses of steel or timber.

In an ordinary roof, immediately below the roof covering, lie the *common rafters* sloping downwards from the *ridge piece* at the apex to the *pole plate* or *wall plate* at the foot of the truss. On the common rafters are placed the roof boarding or battens and over these is placed the roof covering, tiles or corrugated iron, etc. In the more important trusses intermediate support is rendered to the common rafters by *purlins* which in their turn are carried by the *principal rafters* of the truss. The truss has, in addition, a *tie beam* and *struts.*

Trusses.—Figs. 35, 36, 37, 38, 39, 40 and 41 illustrate the different forms of roofs and the names by which they are called. The more important trusses are described in detail below :—



Collar Beam Trusses.—Plate 42(*a*) illustrates a collar beam roof for a span of 16′. The joint between the collar and the rafters is shown to a large scale.

The effect of a collar beam truss is to give more height to the room. They are suitable for spans up to 18′.

King Bolt Truss.—Plate 42(*b*) shows a king bolt truss. The enlarged sketches show the joints at the foot and head of the king bolt.

The tie beam should be set up with a slight " camber ", so that when the weight of the roof bears on the truss the tie beam will not " sag " below horizontal.

King Post Truss.—Plate 43 illustrates a truss suitable for a span of 26′. The pitch is ½ or 26½°.

The truss rests upon stone templates or wall plates.

The dimensions of the different members of the truss are as follows :—

Tie beams 11″ × 5″, which is strong enough to support ceiling joists.

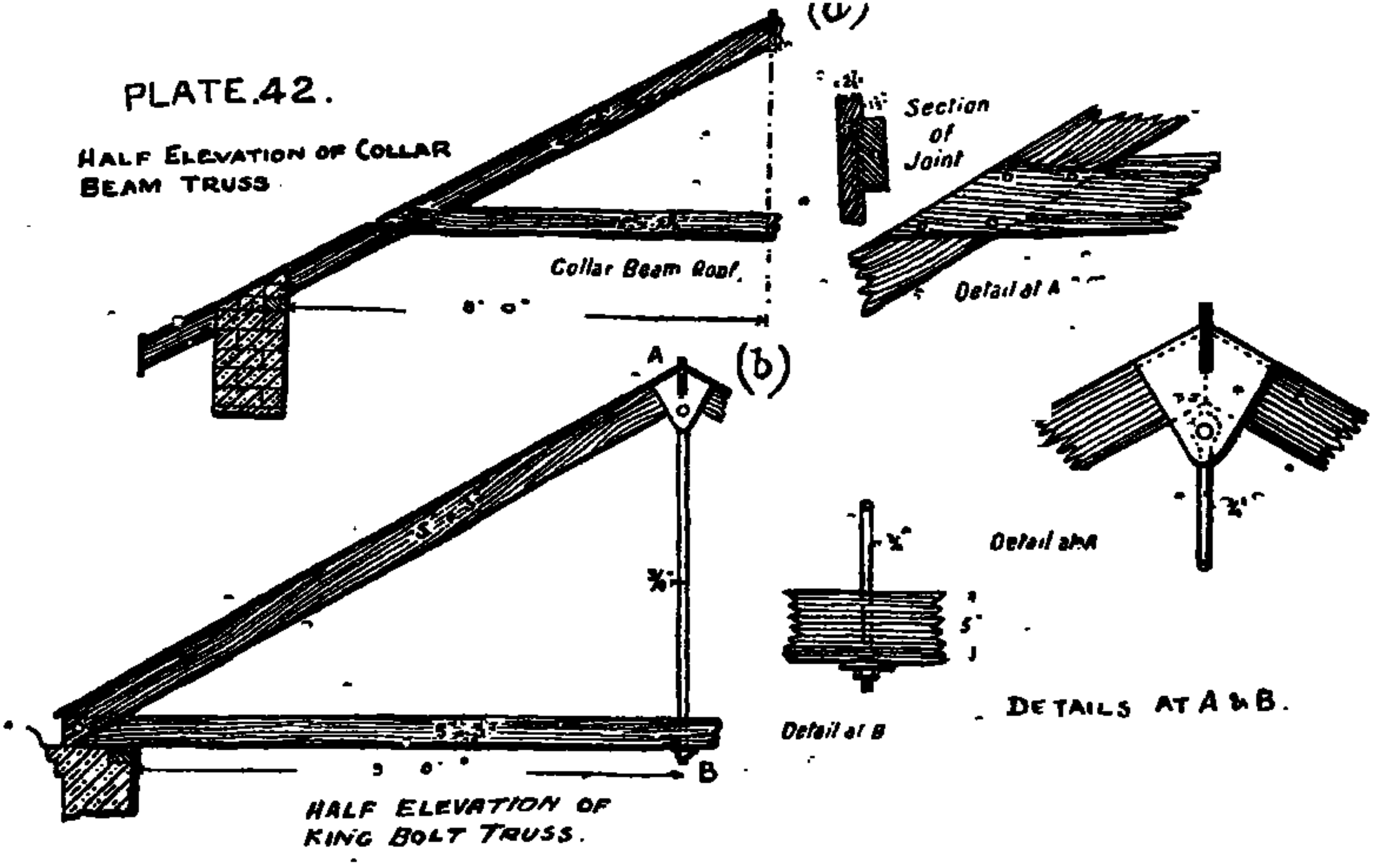
King post, 8″ × 5″, the width of the centre portion being reduced to 5″ to form splayed abutments for the ends of the struts and principal rafters.

Struts and principal rafters each measure 6″ × 5″. The principal rafters are secured at the top by a pair of three-way *straps* and at the foot by a heel-strap with screw-heads.

The tie beam is secured to the lower end of the king post by a *stirrup-iron*. The purlins 8″ × 5″ are notched to the principal rafters. The strut should be placed so as to afford support at the point where the purlins are fixed, *i.e.*, at half the height of the roof. The common rafters are notched to the purlins, their upper ends resting against a 9″ × 1½″ ridge piece and their lower ends against a pole-plate 6″ × 6″.

The addition of 1″ roof board renders the whole ready to receive the slating or other roof-covering. The various joints are shown by

PLATE.42.

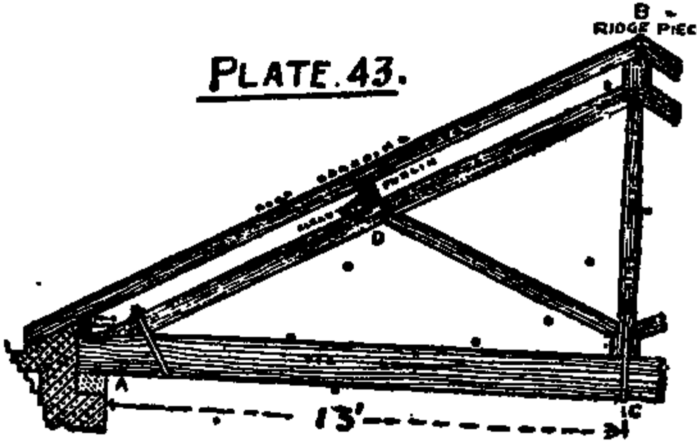


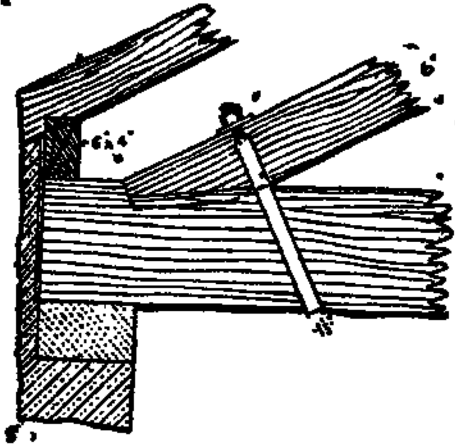
HALF ELEVATION OF COLLAR BEAM TRUSS

HALF ELEVATION OF KING BOLT TRUSS.

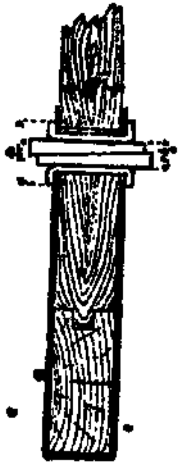
DETAILS AT A & B.

PLATE. 43.

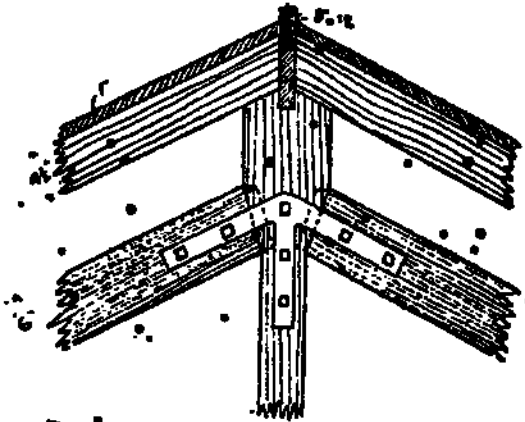




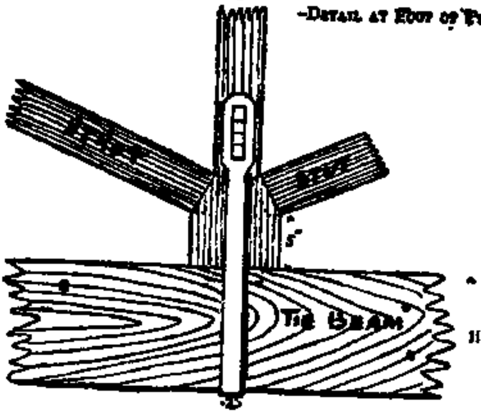
-Detail at Foot of Principal Rafter (A)



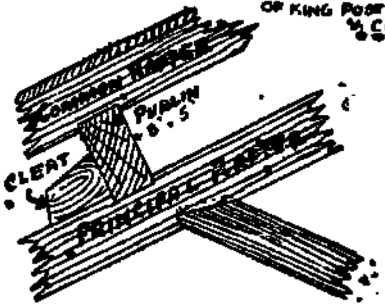
SECTION THROUGH FOOT OF KING POST SHOWING GIBS & COTTERS.



DETAIL AT HEAD OF KING POST (B)



-Detail at Foot of King Post (C)



-Detail at Head of Strut (D)

the enlarged sketches in Plate 43. King post trusses are suitable for spans up to 30'.

Queen Post Trusses.—The example sketched in Plate 44 is a queen post truss for a 45' span. The lower edge of the roof is finished off with a parapet, behind which is placed a gutter bearer to support the gutter. The detail of the joint at the head of the queen post with a pair of three-way straps is shewn to a large scale to explain the method of fixing the purlins, which rests partly upon a *cleat*, nailed to the straining beam. A cleat is also added below the lower purlin.

Queen post trusses are used for spans from 30' to 45'.

Steel Trusses.—In roofs of span 40' and upwards, it is economical to use steel trusses. The dimensions of the different members of steel trusses of different forms for spans of 25' and 50' are shown in Plate 45 *a* and *b*, and the details of the joints and type connections are shown in Plates 46 and 47. The pitch is ¼ or 26° 35' in both examples. The strength of the various members is calculated on the assumption that—

(*a*) The horizontal wind-pressure is 40 lbs. per sq. ft.

(*b*) The roof-covering (tiles) weighs 13½ cwt. per 100 sq. ft., excluding the weight of the truss.

(*c*) The trusses are 10' apart centre to centre.

The members subjected to tension are designed to a working stress of 7½ tons per sq. inch, and short struts (in compression) to a working stress of 7½ tons per sq. inch. Long struts 7 tons per sq. inch. The 25' span truss has both ends fixed.

The 50' span truss has one end free to allow for the expansion and contraction caused by changes of temperature.

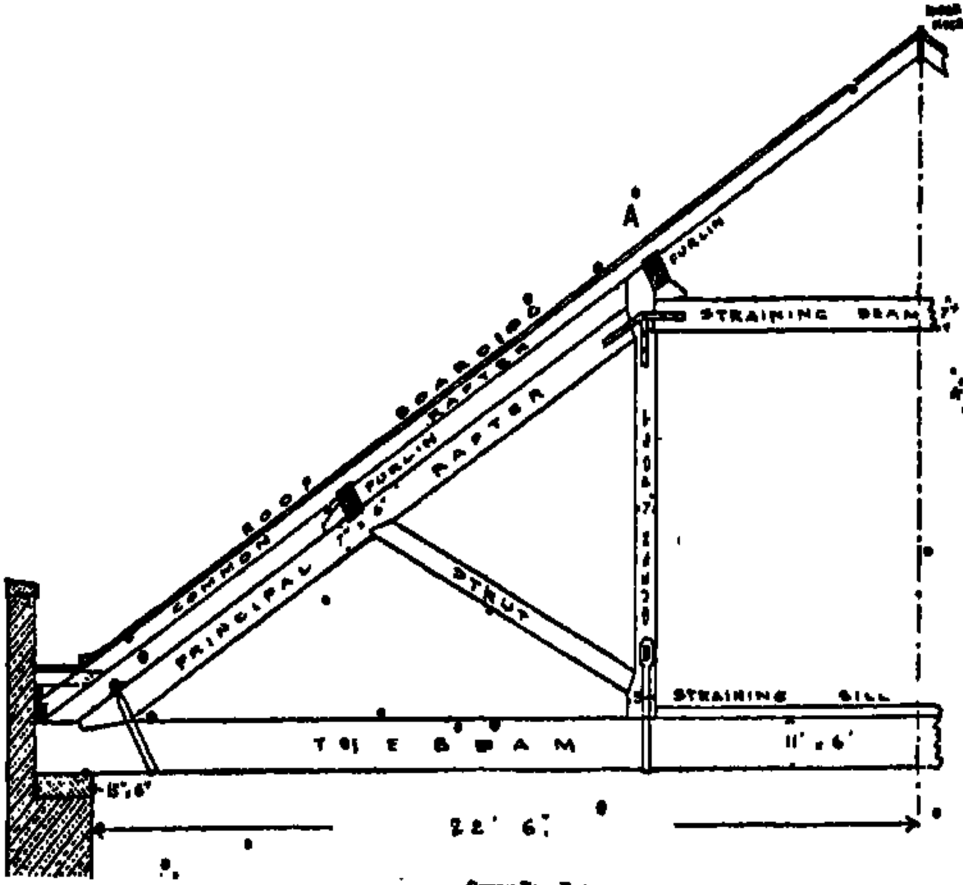
Those members shown in thick lines are in compression, those in thin lines are in tension. For roofs of small spans (25' to 35') the ends of the trusses should be laid on lead sheets and the holes for the bolt holes which secure them should be made slots of oblong form, so that the end may move slightly backward and forward on the lead. That end of the truss is "fixed" to the support from which the prevailing wind blow, the other end being "free". In roofs of large span, the chair or saddle at the "free" end of the truss is supported on steel rollers, so that it can move outwards and inwards with ease under the changes in dimensions caused by changes of temperature.

Roof coverings.—As a general rule the smaller the pieces in which the covering is put on, the heavier will the roof be, and the more difficult to keep watertight owing to the greater number of joints. Substances like tiles or slate usually make better coverings than metals, on account of the slow conductivity of heat of the former. They also preserve an equable temperature in the room, while metal coverings conduct the heat rapidly and make the rooms unbearably hot in the summer, and for the same reason, make the rooms cold in winter, by conducting the heat from the room.

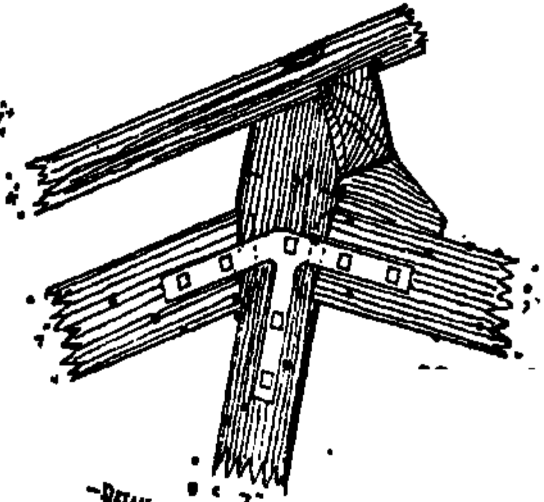
The following specifications are for different kinds of roof covering commonly employed in India :—

Tiled roof covering.—*Tiles* to be sound, well burnt, of uniform colour and size, free from flaws, to ring clearly when struck together.

PLATE 44



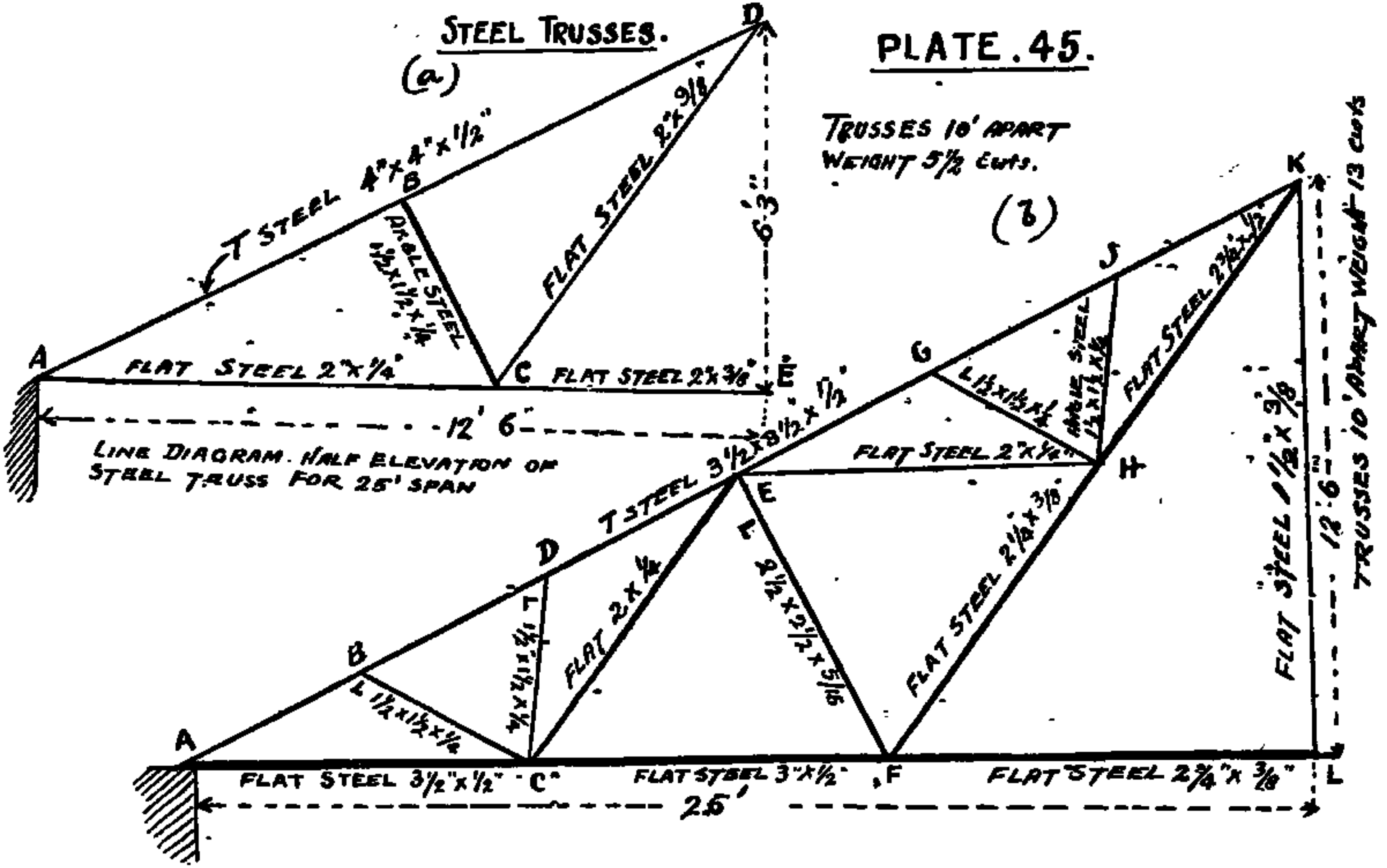
—Queen Post Roof.



—Detail at Head of Queen Post A.

PLATE. 45.

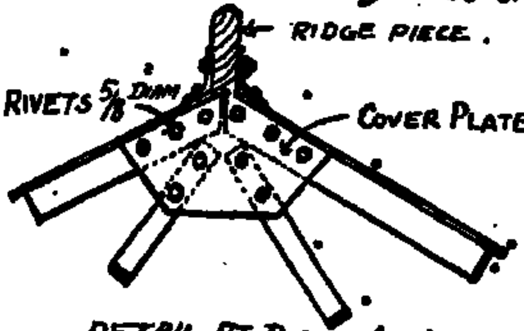
STEEL TRUSSES.



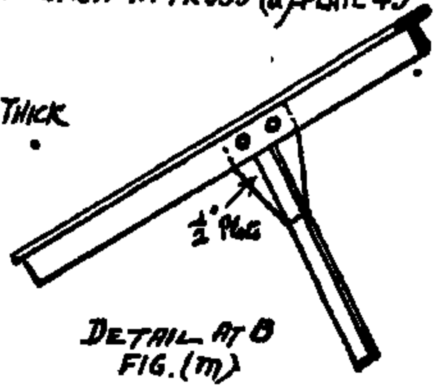
LINE DIAGRAM. HALF ELEVATION OF STEEL TRUSS FOR 25' SPAN

PLATE 46.

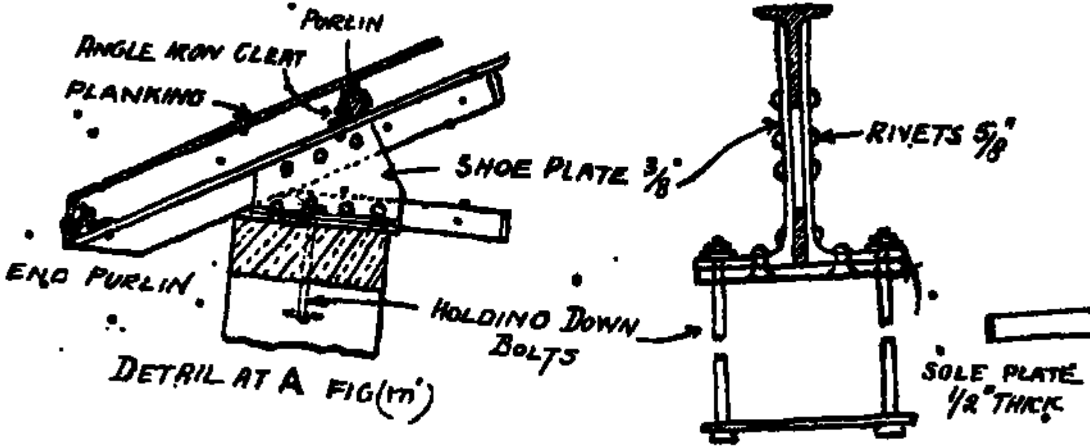
DETAILS OF CONNECTION IN TRUSS (a) PLATE 45



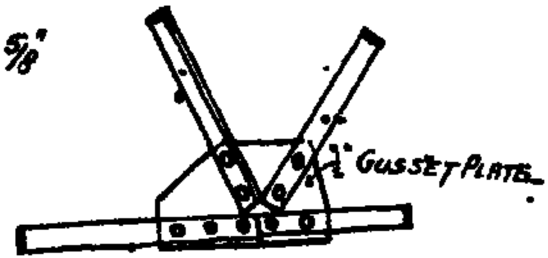
DETAIL AT D FIG. (m)



DETAIL AT B FIG. (m)



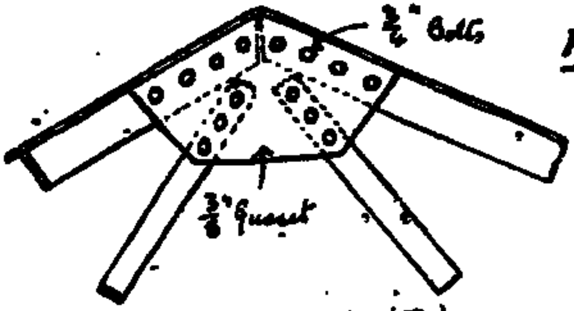
DETAIL AT A FIG (m')



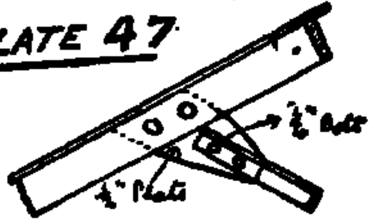
DETAIL AT C FIG (m).

DETAILS OF CONNECTION IN STEEL TRUSSES (b) PLATE 45

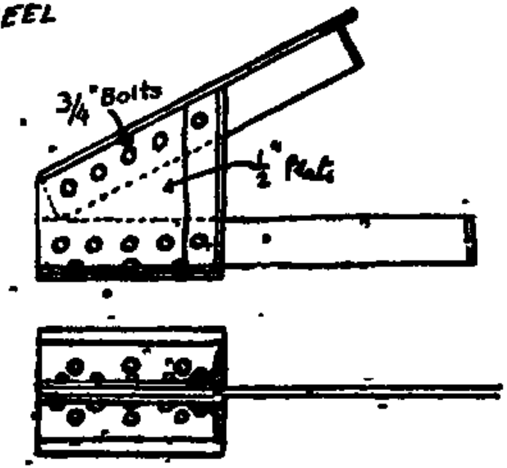
PLATE 47



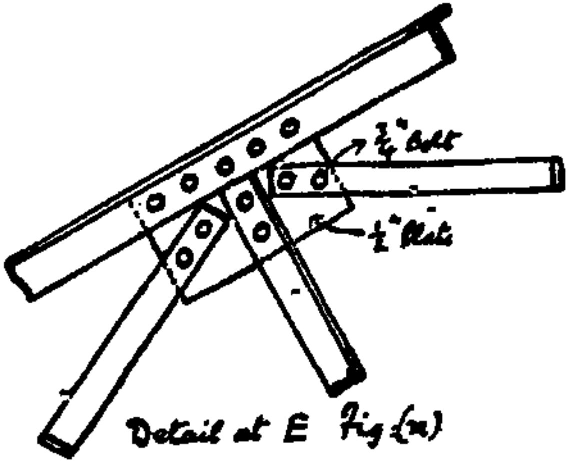
DETAIL AT K FIG (72)



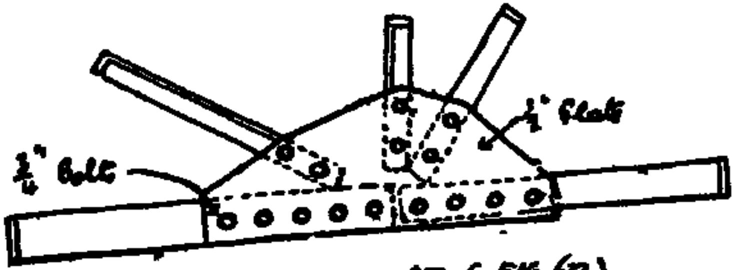
DETAIL AT B FIG (72)



DETAIL AT A FIG (72)



Detail at E Fig (72)



DETAIL AT C FIG (72)

They should be carefully and truly laid at right angles to the eaves and should abut closely to the eaves. All tiles should be soaked in water mixed with cowdung for 12 hours before being placed on the battens (or planking). The eaves, ridges and hips to be set in mortar and pointed.

Plate 48 shows a double-tiled roof covering laid on steel trusses with alternative method of wooden and angle steel purlins.

Corrugated iron roof covering.—The sheets should be sound, and free from injuries due to rubbing of the zinc covering in transit. The sheets are laid with laps of 6" at the ends, and of two corrugations at the sides.

Holes for galvanised screws or bolts to be drilled (not punched) from the inside at a distance of 9" apart on the sides, and at every second corrugation on the ends. All holes to be drilled in the *ridges* of the corrugation (not in the valleys). The sheets to be set carefully on the purlins and fastened to them *by* galvanised iron screws and washers, or by bolts placed 5' apart horizontally, and in the same line, in the direction of the slope, over each purlin.

Eternit slate roof covering.— The slates are fixed over batten 1½" × 1", nailed 9¼" apart centre to centre. Rafters 2' apart centre to centre. In laying the slates, the first row near the eaves consists of slates marked A in Plate 49. Next come the slates marked B, and thence onward of slates marked C, with an overlap of 2¾". Slates A and B are fastened by galvanised iron wire nails, and slate C by nails and copper cramps.

Eighty-two slates cover 100 sq. ft. of roof area. The standard size of each slate C is 15¾" × 15¾" and are obtainable in grey, black or red colour. These slates are not affected by weather, are light and cool, and require but little maintenance. They are also fire-resisting.

Flat terrace roofing is similar to that of a terraced floor. The room is spanned by beams of wood or steel, over which (at right angles) are placed small joists or battens (bargahs) about 3" × 3", at a distance apart equal to the length of a brick. Bricks are laid across the bargahs to form the substratum of the terrace floor. The bricks must butt against each other. Tiles may be substituted for bricks, and should be about 1" square and 1 to 1½" inch thick. If tiles are used they must be laid in two layers, the first layers across the battens and the upper layer set to break joint with the first layer with a thin joint of good mortar between them.

Stone flags may also be used in place of bricks or tiles. They should be 1½" thick and laid on battens of suitable size, and placed at distances of 2' apart centre to centre. Over the substratum of bricks (or tiles or stone flags) a layer of good concrete is laid as already described for floors. The top surface of the roof must be carefully sloped so as to pass off rain water as quickly as possible. The slope should not be less than 1" in 10'. At the junction of the roof covering with the wall a string course, projecting not less than 4" should be built into the wall at a height of 2" above the upper surface of the roof, and the intervening space carefully filled

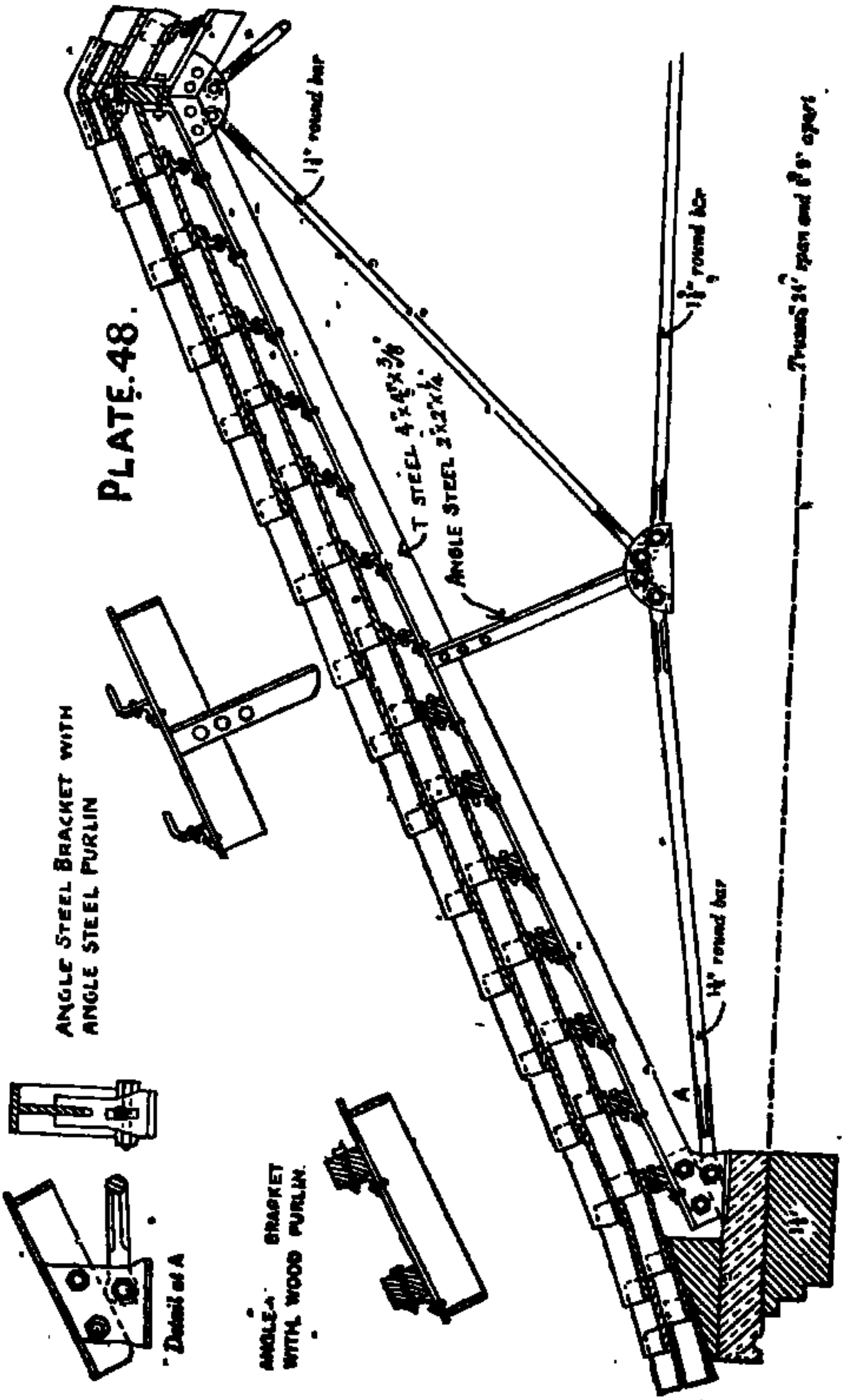
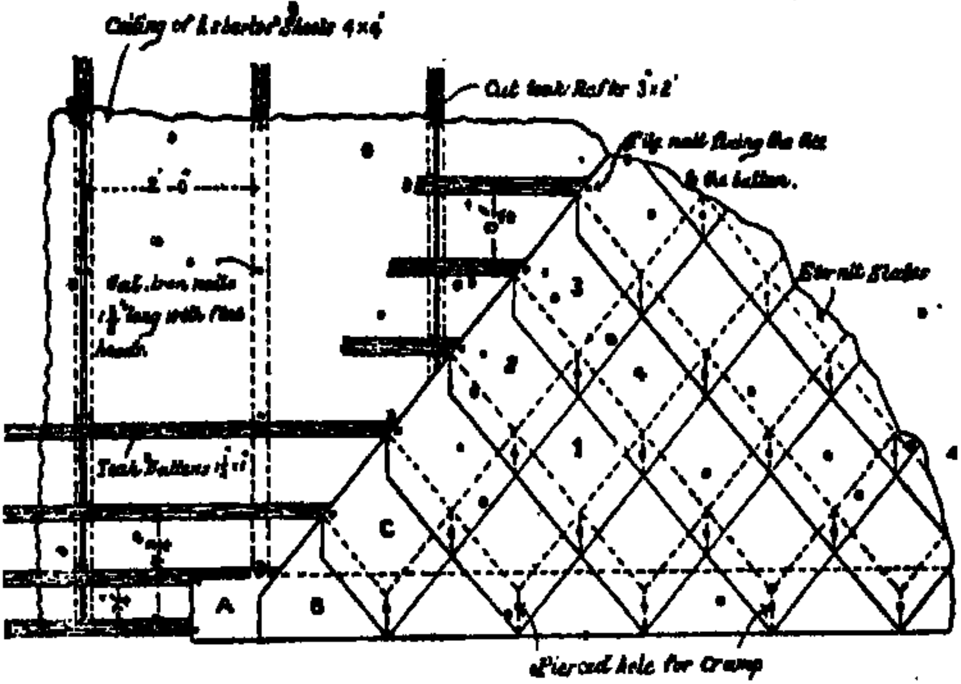


PLATE 48.

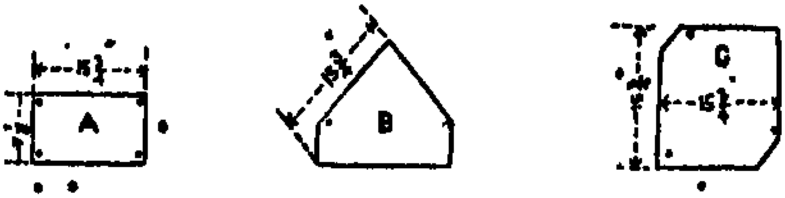
1¼" round bar
1⅜" round bar
1¼" round bar
T STEEL 4"×4½"×3/8"
ANGLE STEEL 3"×2"×1/4"
Trusses 24' span and 8' 6" apart
A
1½"
ANGLE STEEL BRACKET WITH ANGLE STEEL PURLIN
Detail at A
ANGLE BRACKET WITH WOOD PURLIN.

— ETERNIT SLATE ROOF COVERING —

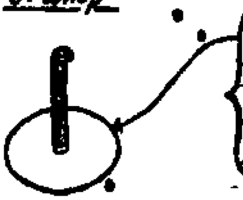
PLATE 49.


Ceiling of Asbestos Sheets 4×4'
Cut teak Rafter 3×2"
Clip nail fixing the tile to the batten.
2'-0"
Eternit Slates
Galv. iron nails 1½" long with flat heads.
Teak Battens 1½×1
3
2
1
4
C
A
B
Pierced hole for Cramp

— Eternit Slate Tiles —



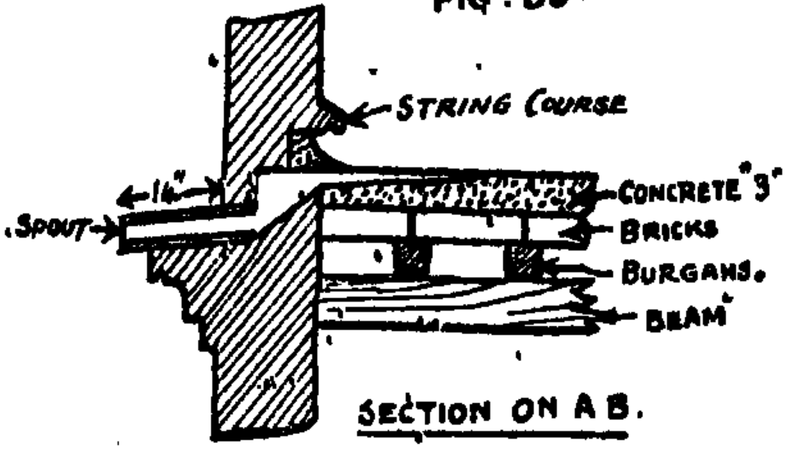
— Cramp —



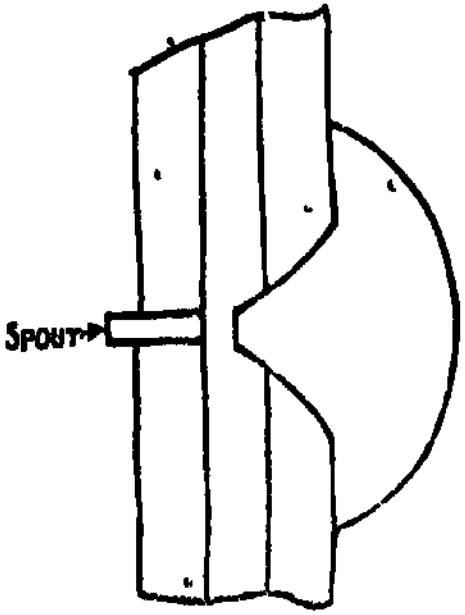
These Cramps are copper discs with copper pin. The disc is slipped under the edges of the slates 2 & 4 at point of contact & the pin passed through & turned down over & binding all together.

in; with concrete to prevent leakage down the wall. Spouts for the drainage as shown in Fig. 50.

FIG. 50



SECTION ON A B.



PLAN OF SPOUT DRAINAGE

Jack arch roofing is similar in construction to Jack arch flooring already described. Arrangements for drainage should be made in all flat roofs as described above.

CHAPTER IX.

Earthwork and ground tracing.

Earthwork operations include the excavations in the "soil." The "soil" may consist of sand, earth, clay, gravel, rock, etc. Earthwork in cutting or in embankment is bounded by slopes, and fails by the sliding of some part of the earth of the slope on that below it. The stability of the soil depends on friction, and the mutual adhesion between the grains. This adhesion is temporarily increased by a small amount of moisture, but decreases when the latter is in excess. The slope at which the sides of a cutting or embankment will stand depends therefore upon the nature and condition of the soil. The steepest slope at which loose earth of a particular kind will stand permanently is called the *angle of repose.* This slope is usually designated as the ratio of the base of the slope to the height. The following table shows the angle of repose of a few soils :—

Material.				Angle of repose.
Dry clay	...	...	...	29°
Wet clay	...	...	...	16°
Dry earth	...	...	...	29°
Wet earth	...	...	...	17°
Gravel	...	...	...	48°
Gravel and sand	...	...	...	26°
Fine dry sand	...	...	...	37° to 31°
Wet sand	...	...	...	26° to 32°

Shrinkage.—In estimating the relative amounts of excavation and embankment required, allowance must be made for differences in the volumes occupied by the material before excavation and after it has settled in embankment. The shrinkage of a few soils is given as follows :—

> Gravel 8 per cent., gravel and sand 9 per cent., clay and earth 10 per cent., light and sandy earth 12 per cent. The volume occupied by rock when it is broken up is more by about 50 per cent. than that of solid rock before breaking it. *Example.*—An embankment of light sandy earth containing a 1,000 c. ft. will require about 1,120 c. ft. measured in excavation to make it. A rock excavation measuring 1,000 c. ft. will make 1,500 c. ft. of embankment.

Heights at which soil retain a vertical face for a short time.—In digging shallow trenches, as in the case of foundations for buildings and culverts, it is economical to leave the face vertical. This may be done temporarily for a depth of 1 to 3′ in moist sand and ordinary surface mould, and to a depth of 5 to 10′ in well drained loamy soil. Ordinary clay will stand temporarily with a vertical face to a depth of from 9 to 12′. When these depths are exceeded it will be necessary to shore up the side of the excavations or cut them to a slope corresponding to that of the natural angle of repose of the particular soil in question ; in digging wells this should be borne in mind. Leaving a vertical face for too great a depth or too long a time has caused loss of life to the diggers. The most dangerous condition for a slope is where water drains out of the adjacent earth through the slope. The slopes of cuttings will stand at steeper slopes than those of embankments. Slopes protected from the action of water by *turfing* (layers of grass) or *pitching* (layers of brick and stone), stand better than unprotected ones. The final decision as to the slope to be given to earthwork will depend upon the conditions noted above. The following are the average slopes permitted :—

Embankments.—

Average soil 1½ to 1 for heights not exceeding 80'.
Average soil 2 to 1 if of greater height.
Reservoir embankments 5 to 1 for slopes in contact with the water.
Cuttings—Clay 2 to 1 when well drained.
3 to 1 } when wet.
4 to 1 }
Gravel, 1 to 1 when not more than 20' deep.
" 1½ to 1 for depths exceeding 20'.
Chalk } will stand perpendicular.
Rock }

Earth in embankment should be laid in regular horizontal courses not more than 4' thick. In high embankments the courses should be slightly concave to prevent slipping.

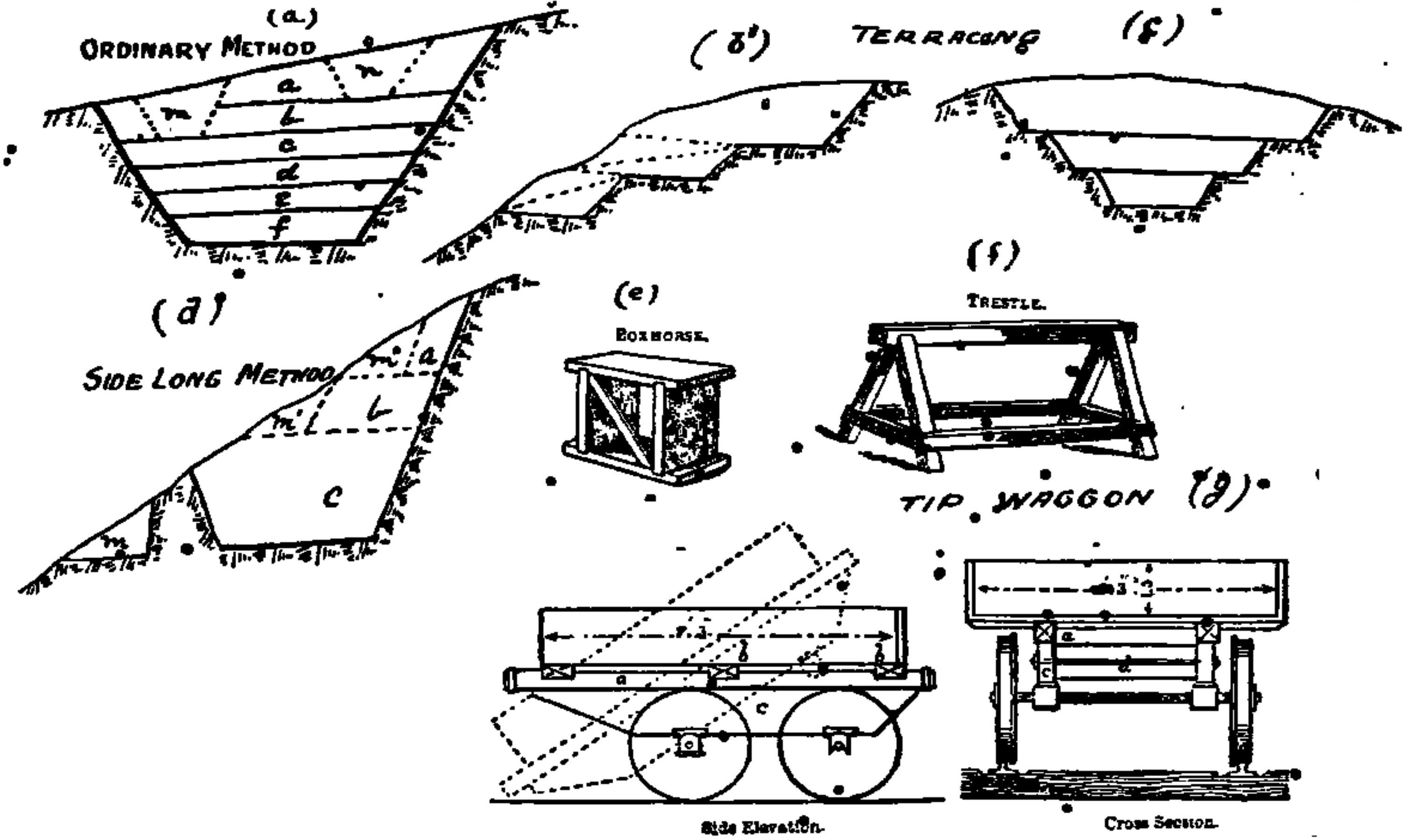
Form of side slopes.—The natural form of earth slopes is a concave curve, in which the flattest portion is at the bottom, but in practice the reverse is often the case, *i.e.*, the slopes are left convex to save excavation. In cuttings exceeding 10' in depth the formation of concave slopes greatly helps in preventing slips and in any case it will reduce the amount of soil which will eventually have to be removed when cleaning up.

Methods of getting earth.—*The ordinary method.*—The excavations are carried out in layers *a*, *b*, *c*, etc. [Plate 51(*a*)]. Each layer is opened out by cuts like *m* and *n* in the sketch, along which carts or waggons may be brought to remove the soil. This method is suitable for long cuttings and permits the employment of a large number of coolies, carts and waggons at the same time.

The method of terracing is illustrated in Plate 51 *b* and *c*. Each terrace has a transport way, on a bench, on one (Plate 51*b*) or both (Plate 51*c*) sides of the cutting. These transport ways are not removed till the completion of their corresponding terraces. Plate 51*d* illustrates the *side long system.* For cuttings on side long ground the principal temporary way runs parallel to the centre line, but at the side of the cutting, which can be attacked at numerous points, and eventually along its whole length. In the sketch *m* represents the temporary way. Different stages, *a*, *b*, and *c*, with separate temporary ways, *m*" and *m*' are often employed with advantage. This method is suitable in steep side-long cuttings in rock.

Transporting earth.—Earth may be transported in baskets carried by coolies, in wheel-barrows, bullock-carts, hand trollies on

METHODS OF GETTING EARTH PLATE 51



rails, bullock-waggons on rails, trucks drawn by locomotives, or by ropes worked by stationary engines.

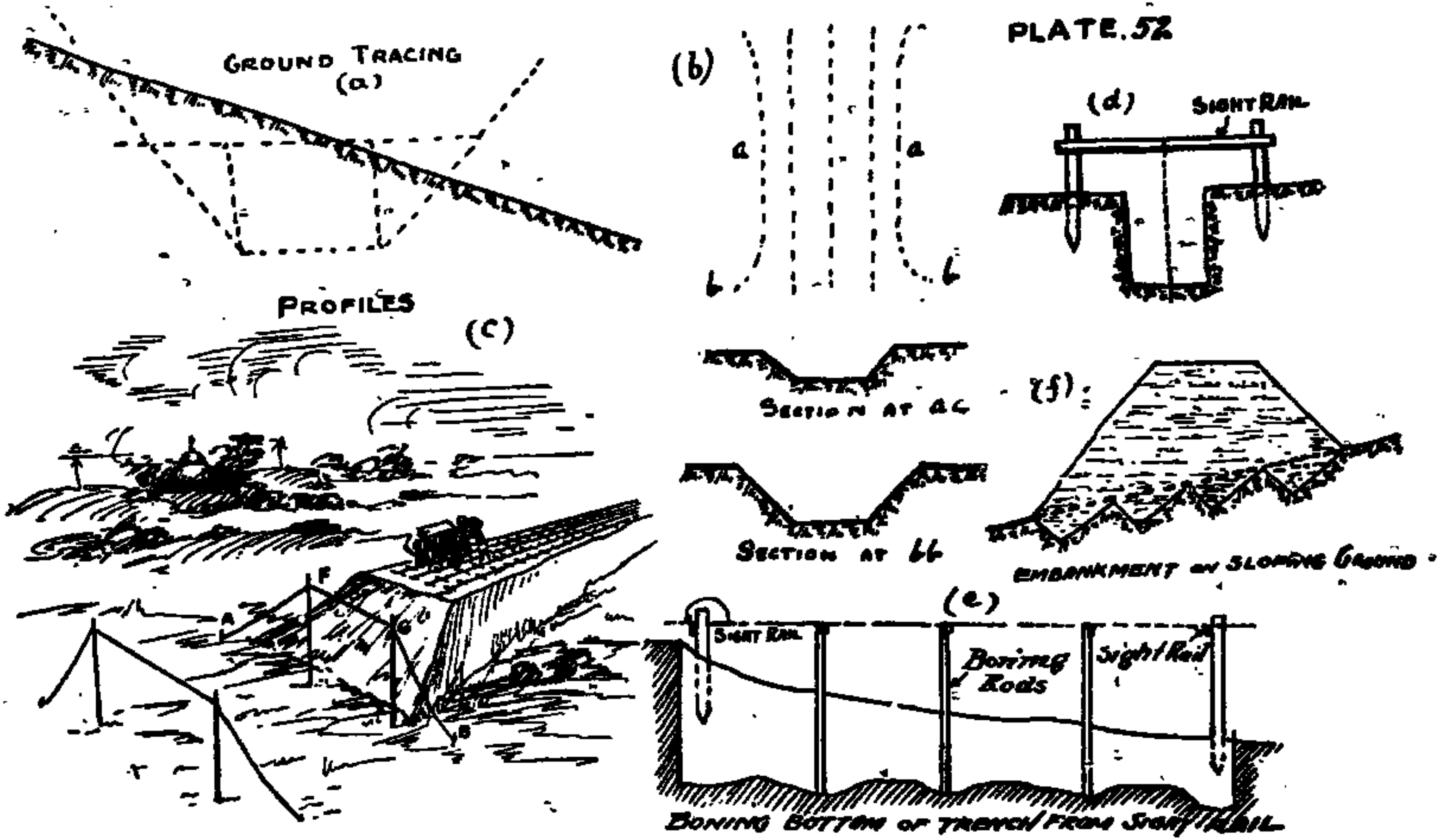
Whichever method is used it should be noted that gradients in transport increase cost. The practical limits of gradients are :—For wheel-barrows, one in thirty. Bullock-carts, one in forty. For temporary ways, one in a hundred. Cost is also increased by higher up throws, unfavourable lifting, repeated throwing, or unnecessary moving of earth. It is essential to have good tools, well formed wheel-barrows, carts, tip-waggons, good temporary ways of rails, or planks, for wheel-barrow runs. A wheel-barrow carrying 2 c. ft., without a plank run, will carry 3 c. ft. with one. A tip-cart carrying 8 c. ft. without a good temporary way will carry 18 c. ft. with one. The wheel-barrows used hold about 2 c. ft. of earth and are usually run on planks not less than 11" wide and 3" thick. The inclination should not as a rule exceed one in twelve. Box-horses (Plate 51*e*) are the best supports for the planks. They are from 1½' to 3' square, made out of 11" by 3" plank. A wheel-barrow run is 20 or 25 yards. Each foot of rise is considered equal to 6' to 9' additional run. If a considerable height is required trestles (Plate 51*f*) may be used to support the planks, but box-horses are stronger and less likely to get out of repair. Wheeling is more economical than carting for distances under 100 yards. A waggon holds about as much as 20 to 30 wheel barrows and goes one-fifth faster. It is therefore equal to 24 to 36 wheel-barrows. If loaded waggons have to be drawn up an incline and the temporary rails are in moderately good order, each foot of ascent may be considered equivalent to 150' of additional horizontal distance. When the height exceeds 12' it is better to use bullock cart than wheel-barrows. For railway embankment and cuttings it is better to use locomotives than carts for distances over 1½ miles. Sometimes the earth excavated for a canal is utilised in making banks that are part of the same earth. But if there is more than is wanted it is called *spoil* and should be placed in a bank called a *spoil bank*. On the other hand, for a bank for which there is no corresponding excavation, pits, called *borrow pits*, must be dug from which the necessary earth is obtained. The spoil banks should be placed with intervals between them so as not to interfere with the surface drainage of the country. Borrow pits should not be dug in a continuous length, since the rain might accumulate and make a drainage line. They consist of separate pits, each about 90' long and 10' feet intervals between them.

Tools.—In ordinary work on a small scale the tools used in India are the "phaorah" or "khodali," pick, basket, and barrow. It pays to use good tools. The phaorah is used for digging and lifting the earth into the basket or barrow. If the earth is hard it is loosened with a pick. If the work is on a large scale and the distance the soil has to be carried great, it is economical to lay rails and run waggons or trucks by hand or steam power. The waggons are made with their bodies hinged to the frame work carried by the wheels so that the body may be tipped over and the earth thrown out. One form of tip waggon of capacity about 60 c. ft. clay, is shown in Plate 51 *g*. The resistance of such a waggon is about 80 lbs. per ton. Two such waggons could be drawn by one horse. The rails used for the temporary ways weigh from 25 to 30 lbs. per yard.

Ground tracing.—The first operation in any earthwork is to set out the edges of the work. In the case of a building or culvert the plan of the foundation trenches is first worked out on paper, showing all centre lines and the actual edges of the trenches. This plan is then transferred to the actual sight, and all edges and salient angles pegged out on the ground to the full size. The bottom width of the cutting is marked out on the ground surface by lines parallel to the centre lines. For a canal the centre line is laid down by surveying instruments and pegs are driven at intervals of 100 feet. A cord is stretched along these pegs and a line is nicked out with the "khodali" to mark the centre line on the ground. The depth to be dug below each peg is recorded in the measurement book against the peg's number. The depth is ascertained exactly by the level. In excavation the peg is left with the pillar of earth underneath it in the channel. This serves as a reference to measure the depth of the excavation without the necessity of again using the level. The bottom width is now marked out on the ground surface by lines parallel to the centre line. The centre portion of the excavation is usually removed first and the side slope struck afterwards. The edges of the slopes are marked out by running lines from point to point to mark the top of the slopes. The distance from the bottom width to the edge of the slope will of course vary with the depth of the excavation (*see* Plate 52 *b*). If the ground slopes across the line of the canal the breadths of the slopes will be more on the higher and less on the lower side than on the flat ground (*see* Plate 52 *a*). If the work is an embankment instead of a channel, the setting out is similar, viz., centre line, top widths, and foot of slopes. In this work, however, *profiles* are erected at each peg. Poles are fixed at the breadth of the top of the embankment and the correct height is then marked on them by attaching a cord F G. The side widths being also marked by the cords A, F, and G, B, the earth is then piled up to the outline made by the cords (Plate 52 *c*).

Levelling by the boning method.—The operation of levelling trenches, etc., is often performed by boning rods of which there are three in a set. Two of these are levelled at a distance of about 10′ apart. The third rod is then levelled at a similar distance. The centre rod is then removed and the level transmitted to any site along the line, by sighting or boning over the first and third rods. It is essential that the bottom of trenches dug for foundations be level. This is ensured by erecting two sight rails over the trench as shown in Plate 52 *d*. The side parts of these sight rails should be so placed that they will not be disturbed by subsequent operations. A level line is sighted through the level end and marked on the sight rails. The cross bar is then fixed in each and a mark is made on the bar plumb over the centre of the trench. The width of the trench is marked out on the ground with cord and pegs as already described and the excavation begun. If the excavation is deep and the vertical face of the trench is excessive the sides will have to be shored up as described in the chapter on Foundations. When the full depth of the trench is approached a number of points are sunk to the exact depth by means of boning rods, the tops of which are sighted between two of the sight rails as illustrated in Plate 52 *e*. The remaining parts of the bottom of the trench are taken out level between the points so determined. A similar process is employed for excavating a trench for a drain. In this case, however, the sight

PLATE. 52


GROUND TRACING
(a)
(b)
a
a
b
b
SECTION AT aa
SECTION AT bb
(d)
SIGHT RAIL
PROFILES
(c)
F
A
G
B
(f)
EMBANKMENT ON SLOPING GROUND
(e)
SIGHT RAIL
Boning Rods
Sight Rail
BONING BOTTOM OF TRENCH FROM SIGHT RAIL

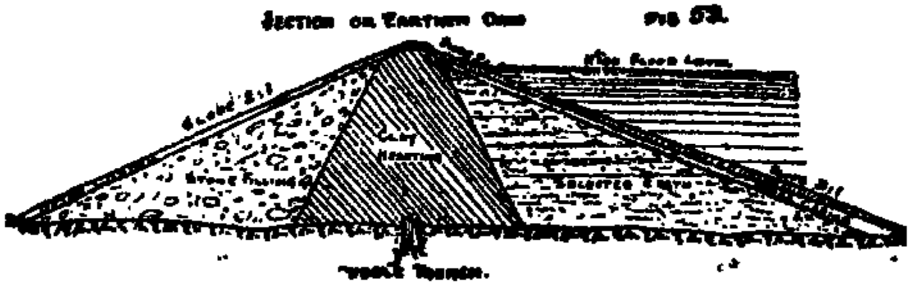
rails are given : a difference in level, corresponding to the required fall of the drain.

Earthwork for roads.—The following notes on Earthwork for roads are extracted from Captain Marryat's Notes on work compiled for the use of the Public Works Department:—The embankment will generally be formed of earth obtained from pits excavated along the side of the road. The ground to be occupied will be cleared of all large bushes or trees, but it is not necessary to grub up roots, or grass, or to remove the surface soil. The surface of sloping ground on which an embankment is to be erected should invariably be prepared to receive the earthwork by having cut in the slope a sufficient number of footings or benches forming a right angle with the slope of the embankment (Plate 52 *f*). No mud, slush, or watery stuff from wells or springs, and no decayed vegetable matter or rotten stuff of any kind should be allowed to be put into embankments. All enbankments are to be raised in regular layers, rammed and consolidated being moistened with water if necessary. They will be carried to the full width of the slopes in all cases, so that no additions may be required to the slopes after the bank is made up to formation level. All lumps and clods of earth are to be broken up so as to allow of a regular subsidence of the earthwork throughout. In carrying up embankment, the full allowance for shrinkage shall be made first, so that no addition of earth will be required after settlement to bring the bank to its full dimensions. The tops of all embankments are to be brought up to the levels set out, and neatly levelled off. The slopes are to be dressed to the required inclinations and neatly trimmed. In carrying embankments over a bridge or culvert, the earthwork shall be brought up evenly on both sides of the structure so that the pressure may be equalised. In filling in the approaches of a bridge, or the spandrils between arches, the earth shall be raised simultaneously with the wing walls in the former case and with the face wall in the latter, in order that the filling in may be well trodden down under the feet of the workmen. In filling in basements and backings to revetments, the earthwork shall similarly be brought up level as the masonry proceeds. In cutting through high ground the excavation shall be made in steps down to formation level with sides perpendicular, or nearly so, and the slopes formed afterwards. The sides of cuttings for roads in loose soil are to be protected by catch-water drains above the cuttings. At the foot of the slope will be a small berm and between this and the edge of formation level, a catch-water drain. All " dead men " shall be removed from cuttings when no longer required for measurement purposes. All temporary pathways, ramps, etc., are to be dressed off neatly and the whole work properly finished. The measurements of earthwork will be taken from the pits furnishing the earth which shall be numbered, the numbers being marked on pegs driven into the corner of each pit to facilitate check measurement.

Earthwork in canals.—The excavation shall be carried out according to design, with accurately graded bedfall and sides properly sloped. The excavation is done by first cutting a centre trench with vertical sides and then trimming the slopes. The excavated material, if not required for embankment, should be thrown up in spoil banks in 12" layers, with neatly made slopes and top, a suitable berm being left between the top of the bank and the edge of the excavation. When the banks have to retain water, they should be formed with a core of sound earth, with a covering. The hearting or core should extend to 2′ above flood surface level in banks of more than 8′ height, and should be 3′ wide at the top with side batter of 1 in 4.

Construction of earthen reservoir dams.—The embankment to consist of a water-tight hearting of clay or clayey earth, with a casing, both in front and back, of clay mixed with gravel. The clay hearting is intended to make the dam water-tight, and the casing to afford protection to the hearting against the effect of alternate saturation and extreme dryness. The casing both front and back shall be 3′ thick at full supply level measured at right angles to the slope, increasing at the rate of 1′ for every 20′ vertical depth. The material, freed of all clods and lumps, shall be laid in continuous layers with a slight slope towards the centre, making a concave curve, the centre being 3″ to 6″ lower than the outer edges. The material should be spread in even layers of 6″. Water should be sprinkled to sink about ¾″ in depth into the completed layer before the next layer is spread, so as to ensure complete union between the two.

Where it is proposed to protect the outer slope of embankment with grass, the outer casing should be finished off with a top layer containing a sufficient admixture of soil favourable for the growth of the grass. The inner slope of embankment should be protected with stone pitching. When circumstances permit, one rainy season should be allowed to elapse after constructing the slope to allow for consolidation before pitching is commenced. The stone to be good, hard, quarry or boulder stone such as will not weather on the surface. It is to be roughly hewn or squared with the hammer to ensure the stones setting fairly one on the other so as not to expose the earthwork below. The depth of the pitching to be 6″ at the bottom of the slope, increasing uniformly to 18″ at highest flood level and again decreasing in the same way to 12″ at the top. Fig. 53 shows a cross section of a dam in use, where sufficient clayey soil is not available. In this type only a core of that material is provided in the middle of the embankment directly over the puddle trench. The space between the core and the outer casing should be filled with some selected material for the front half of the dam, while rock debris, gravel or sandy soil should be preferred for the part in rear



of the core. The top surface of embankments should be 3′ above flood level, so as to preserve it from inundation.

Surface drainage cuttings.—Rain falling in a cutting should be led out by side drains at the foot of the slopes. No water from the adjacent grounds should be allowed to drain into the cutting. To prevent this, drains should be constructed along the top of the cutting, thus intercepting the water before it can reach the cutting. All surface water is thus led along these drains clear of the cutting.

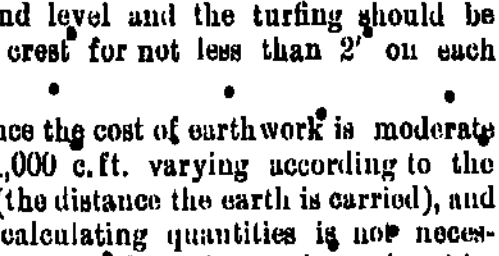
Turfing.—The outer slope of an embankment should be sodded with grass; "doob" is the best. The turfing should be carried out during the rainy season. The sods should be at least 2″ thick and should be laid slightly overlapping one another.

Watering should be continued until well rooted. In the case of a canal the inner slopes may be turfed to 2′ below full supply level, the lower portion being dressed only. In roads, both slopes should be turfed to the ground level and the turfing should be carried over the edge of the crest for not less than 2′ on each side.

Estimating earthwork.—Since the cost of earthwork is moderate and the rate at so much per 1,000 c. ft. varying according to the nature of the soil, the "lead" (the distance the earth is carried), and the "lift", great accuracy in calculating quantities is not necessary. The use of the correct prismoidal formula may be replaced by determining the area of cross sections by taking the mean depths to one place of decimals, between two contiguous pegs, and multiplying this area by the distance between the two cross sections under consideration.

For example:—

Let D be the depth at one centre peg, and D′ that at the next peg. The mean depth $= \frac{D+D'}{2} = d$, say. In the figure let B be the bottom breadth of a cutting (or the top breadth of an embankment). Then the area of the centre rectangular portion is Bd, and of the side pieces $2\,\frac{sd \times d}{2} = sd^2$, where s : 1 is the slope of the sides. The whole area of the cross section is $Bd + sd^2$, and if L is the length between two successive pegs the volume is $L\,(Bd + sd^2)$.



CHAPTER X.

Roads and Culverts.

Roads.—The object of a road is to provide a way of travel, and for the transportation of goods from one place to another. Roads differ much in their nature according to the purpose for which they are required. A road between two villages will differ from one in a large town. In the former the problem is to provide the hardest and most durable surface consistent with economy, to lighten the cost of transportation by reducing the resistance to traction, and to render travel easy and comfortable. In town or city streets, however, the comfort of both those using the street and of the occupants of the adjacent houses will be largely affected by the freedom of the road surface from noise and dust. The safety of the pavement in use, its effect upon the health of residents, and its cost have all to be considered. To adjust to the best advantages these various elements, frequently quite discordant with each other, require judgment and experience. Local conditions must always be considered, such as drainage, availability of various materials, nature of traffic, needs of the residents in the neighbourhood, choice of site of bridges when crossing a river, etc. The important factors requiring consideration are discussed below under the following heads :—

Traction and Gradient.
Metal.
Cross Section.
Construction.
Maintenance and Repairs.
Drainage and Culverts.

Traction and Gradients.

The resistance to traction of a vehicle on a road is due to—

(*a*) the gradient or inclination of the road,
(*b*) the axle friction,
(*c*) the rolling resistance.

The total tractive force necessary to haul a load up an inclined road is the sum of the forces necessary to haul the load on the same surface when level, plus the force necessary to overcome the resistance due to the gradient.

The axle friction varies with the nature of the bearing surfaces, and for vehicles of similar constructions is proportional to the load.

The rolling resistance is due to—

(*a*) irregularities on the surface of the road,
(*b*) that of a wheel rolling on the surface called the rolling friction.

The resistance due to (*a*) is the horizontal force, necessary at the axle, to raise the weight on the wheel to the height of the obstacle. For small irregularities, this resistance is approximately inversely proportional to the diameter of the wheel. The effect of small irregularities, however, is due more to the shocks and concussions produced by them, then to the lifting action of the obstacles, and the resistance due to uneven surfaces is greater at high than at low velocities. Rolling friction is probably due to the compressibility of the road surface. The wheel indents the surface and is then always forcing a wave of the surface before it, or is climbing an inclination caused by its weight upon the surface of the road.

Metalling.

The surface of the road should be hard, tough, binding and smooth. It should be well drained and laid on a stable foundation. The road should be a monolithic body of such strength that the separate stones used as metalling shall move as little as possible under the weights and rolling of the traffic. The conditions of toughness and hardness are more or less met by the various substances used as metalling, *e.g.*, stone, kankar, bricks, wood, bituminous materials. With regard to *stone* the qualities necessary are :—Power to resist compression, abrasion, action of weather, and its power to assist cementation. The following are suitable for first class roads : *Syenite, granite, Trappean Rocks, limestones,* including *kankar.*

Second or third class roads may be metalled with gravel. This, if of a flinty character, and not too much mixed with earth makes good roads for light traffic.

Bricks may be used when nothing else is available, but they do not make good roads. The traffic on a brick metalled road should be of the very lightest.

Bituminous material consisting of mixtures of sand, stone and bitumen make excellent roads and are as largely used in the bigger towns and cities. The methods of laying the metal will be dealt with under the head " Construction ".

Cross Sections.

The cross section of a road should be based on the following considerations :—

(*a*) Drainage.

(*b*) Value of the land through which the road passes.

(*c*) Nature of the country, *i.e.*, whether fairly level or in the hills.

To provide for *Drainage* the cross section of the road is " barelled ", *i.e.*, it has a " camber ". The only object of camber is to pass off the water as quickly as possible to the side channels, as water is even a greater enemy to most surfaces than traffic. The objections to excessive camber are :—

(*a*) The tendency to cause the traffic to keep to the centre of the road, thus causing longitudinal hollows along the road in which water may settle.

(*b*) The tendency to cause side slips, both of self-propelled vehicles or of a horse.

(*c*) A high load is often tilted at such an angle over the footway, as to cause collisions with lamp posts, branches of trees, and the like.

Many experts have given various opinions on the question of camber, varying from 1 in 24 to 1 in 40. The camber shown in the sketches (Plate 54) have been recommended for Indian roads. It may be taken at 1 in 36. The width of the cross section of the road will depend upon the *value of the land*. For a first class road in land of ordinary value the cross section given in Plate 54*a* has been recommended. Plate 54*b* shows the cross section of a first class road passing through land of high value. The section of a road in *hilly country* is given in Plate 54*c*.

Construction.

The remarks under "Embankments" and "Cuttings" in Chapter IX apply equally to roads in embankment and cuttings.

Collection of metal.—If broken stone is to be the metal it should be tough, durable and be broken so as to pass in every direction through a 2" ring for underlayers, and through a 1½" ring for the surface. No material should be stacked until it has been thoroughly screened and free from all earth. When ready it should be stacked entirely clear of the roadway, either upon the berms and platforms provided for the purpose, or at the foot of the side slopes. Comparatively large heaps are more economical than small ones. The height should not be less than 2' and no heap of less height than 1' should be measured. The length and breadth of the heap will of course depend on the quantity required and the shape of the site.

Spreading and Consolidating.—The thickness of metal to be laid on new and important roads should not be less than 9". The actual thickness will depend upon the nature of the traffic. On roads of less importance the thickness of metal should not be less than 6". The "formation" of the earthwork should be thoroughly drained, cambered and rolled before the metal is spread.

The banks should be exposed to the whole of a wet season, if possible, before the metalling is added.

Where ordinary (not steam) rollers are used, the metal should be laid in layers of about 3", the lower layer being *nearly* consolidated (not completely) before the next layer is added. The metal should be thoroughly saturated with water, if the rainfall is insufficient, during the rolling. The watering and rolling should continue until the surface is thoroughly hard and smooth. No more "binding" of sand should be used than is absolutely necessary to ensure the metal binding. Ramming is of little use unless done with a large number of men (say 16) working in unison in four consecutive rows, using abundance of water. The work of each portion cannot be considered finished till the water has been completely expelled under the rammers, and the surface left smooth and hard. When rollers are used the weight should be at least ¾ ton per foot of length. As a finishing coat a thin layer of sand is applied over the surface of the consolidated metal.

The above description of consolidating and spreading stone metal applies equally to broken bricks and kankar. If, however, broken bricks are used there should be a "soling" of well burnt bricks on new roads. The soling bricks should be laid in rows across the lower.

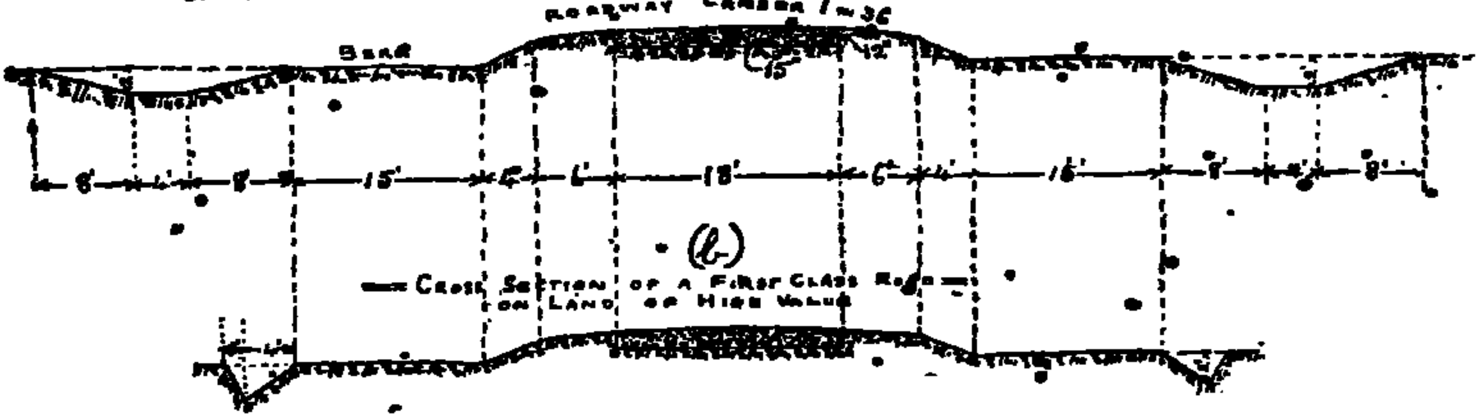
The latter will be laid longitudinally with the road.

ROADS

PLATE 54.

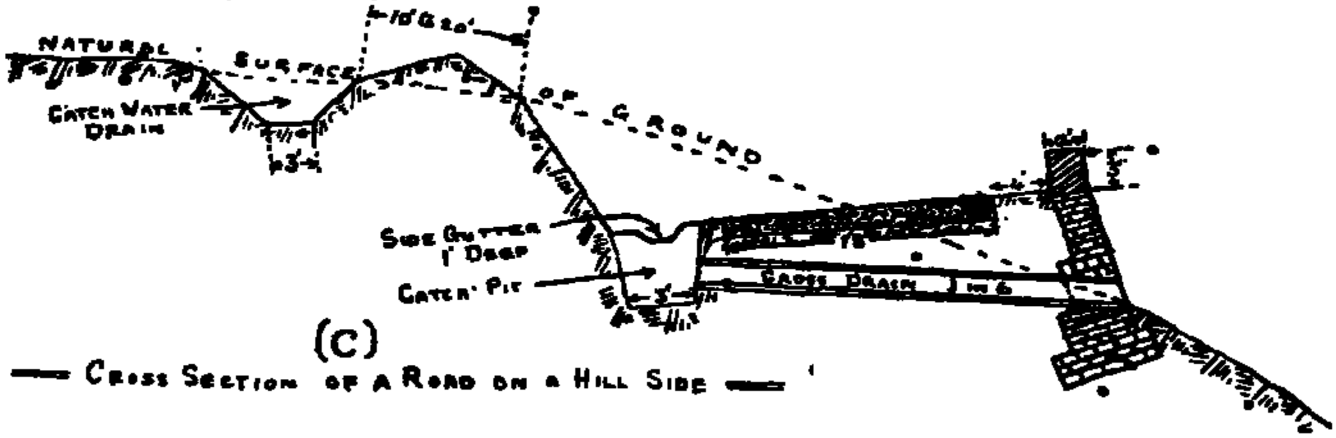
(a)

CROSS SECTION OF A FIRST CLASS ROAD ON LAND OF ORDINARY VALUE



(b)

CROSS SECTION OF A FIRST CLASS ROAD ON LAND OF HIGH VALUE



(C)

CROSS SECTION OF A ROAD ON A HILL SIDE

Pitch grouting.—Upon a 10" foundation of hand-pitched rock, laid and consolidated as for a stone metalled road, a layer of stones 2½" gauge shall be spread evenly to a depth of 3½". This layer after being rolled shall be grouted with a hot mixture of pitch and creosote oil and again rolled while hot until the mass is thoroughly consolidated. A second layer of stones of 1½" gauge, 2" deep, shall then be laid, preferably while the lower layer is still hot. After being rolled dry it shall be grouted in a similar manner with the pitch mixture. The surface shall be covered with a sprinkling of dry chippings and the whole shall be again rolled until consolidated. The road shall be laid to an approximately circular camber with a cross fall from crown to channel of 1 in 84.

The pitch mixture used for grouting shall consist of coal-tar pitch and creosote oil properly blended and boiled together in a pitch boiler. Immediately before being put on the road an equal quantity of fine sand heated to 400°F. shall be added to the pitch mixture which shall then be kept continually stirred till spread.

Tar Macadam.—The aggregate consists of stone 75 per cent. of 2½" gauge and 25 per cent. of smaller material, the top surface being finished with stone varying from 1 to ⅝ of an inch. The stone is dried and mixed with boiling tar in a rotary tar macadam mixing machine, kept hot during the whole period of mixing. The material is laid cold on the surface, which has been excavated for the purpose, and rolled into place.

Maintenance and Repairs.

To maintain a broken stone road in good condition it is necessary that it be frequently cleaned of mud and dust, and that the surface drains be kept open to ensure the prompt discharge of all water that may come upon the surface of the road.

The nature of the repairs will depend upon the character of the materials used for metalling as well as upon the weight of the traffic passing over it. If the road metal is of soft material which wears easily, it will require constant supervision, and small repairs whenever a rut or depression appears. Material of this kind binds readily with new material and may in this manner be kept in good condition without difficulty, but if not attended to as soon as wear begins to show, it will very rapidly increase, to the great detriment of the road. The material used for repairs should be the same as that of the road surface, and not fine material which would soon reduce to powder under the loads which come upon it. Careful attention to minute repairs will keep the surface in good condition until it wears so thin as to require renewal. "The proper way to repair a road is to first carefully scrape off the mud, then to cut out the hole or depression in a rectangular shape. The depth of the excavation should be amply sufficient and the bottom well hacked to form a key for the new metal. The excavation should then be filled with new material broken to a gauge of about one inch and, if a small patch, well rammed into place with the addition of some suitable binding and a little water. If the patch is of sufficient size, a light roller should be used instead of a rammer. . . . . After completion of the patch, it should be dusted over with clean, sharp sand or other suitable material."

Drains and Culverts.

Drains.—The surface drainage of a road is provided for by a ditch or drain on each side of the road when the latter passes through level country, or is in cutting. The drains should lead the water to the natural water course of the country. On hill roads catchment drains about 3′ wide and 2′ deep should be cut in the hillside about 10′ or 20′ from the top edge of the slope. These will prevent water rushing on to the road from the hillside. The drainage of the road itself is provided for by the side gutters or drains along the inside of the road, which should discharge at intervals into culverts which pass the water under the roadway. These culverts or cross drains will be required at intervals of about 200′ along the whole road. The minimum size is shown in Fig. 54 *c.* The floor of this culvert should slope not less than 1 in 6, and a catch pit 3′ square with floor one foot below the floor of the culvert should be provided to catch the silt washed down the side gutter.

Culverts and bridges are used to carry the road across the natural drainage of the country. The level of the road surface is usually very little above the crown of the arch, and there is therefore little space for heading up the water above the top of the archway. It is usual therefore to estimate the waterway up to springing level only, and it may be assumed that the velocity of the water under the culvert is 10′ per second. The foundation should be designed for this velocity. The crown of the arch should be above the natural flood level. For catchments up to 100 acres one square foot of waterway for every 2½ acres of catchment has been found sufficient. Catchments between 100 and 700 acres would require one square foot of waterway for every 4 acres of catchment. The "catchment" is that area of the ground over which rain falls and then drains off into one line of outfall or water-course.

Plates 55, 56 and 57 show a few types of culverts which may be used to pass the drainage under the road. The different parts of the culverts are named on the sketches. The "waterway" or "vent" in any culvert should be at least 2′ square so that it may be easily entered and cleaned out when necessary. Its actual size will depend upon the quantity of water to be passed.

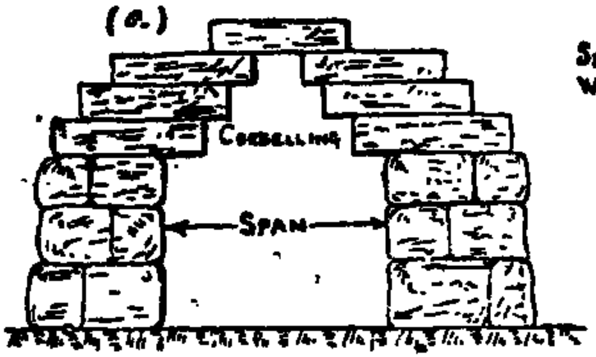
The vents may be covered over with flat stone, or arched according to circumstances.

When there is any *rush* of water and the soil is bad, the culverts should be provided with a "floor" protected at the end by a "retaining wall." If there is a great weight of embankment on the culvert "inverted arches" may be used to form the bottom of each vent.

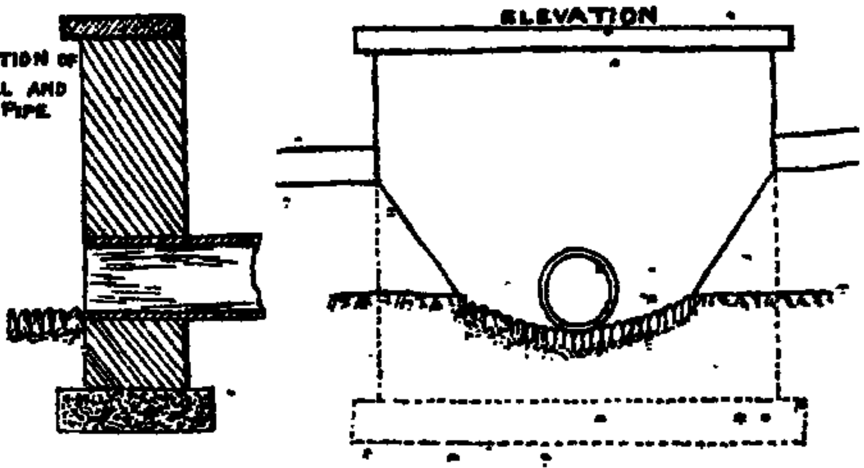
Approximate dimensions are as follows :—

Total length of culvert under an embankment is equal to the breadth of the road plus twice the length to which the slope runs out on either side of the vent.

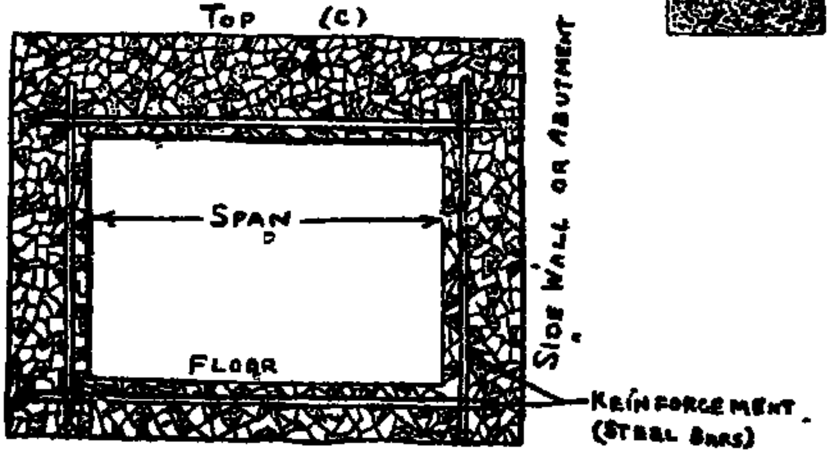
The side walls or "abutments" of the culvert may have a thickness of a quarter of the "span", provided the thickness is not less than 1½′.



Flat Stone Culvert



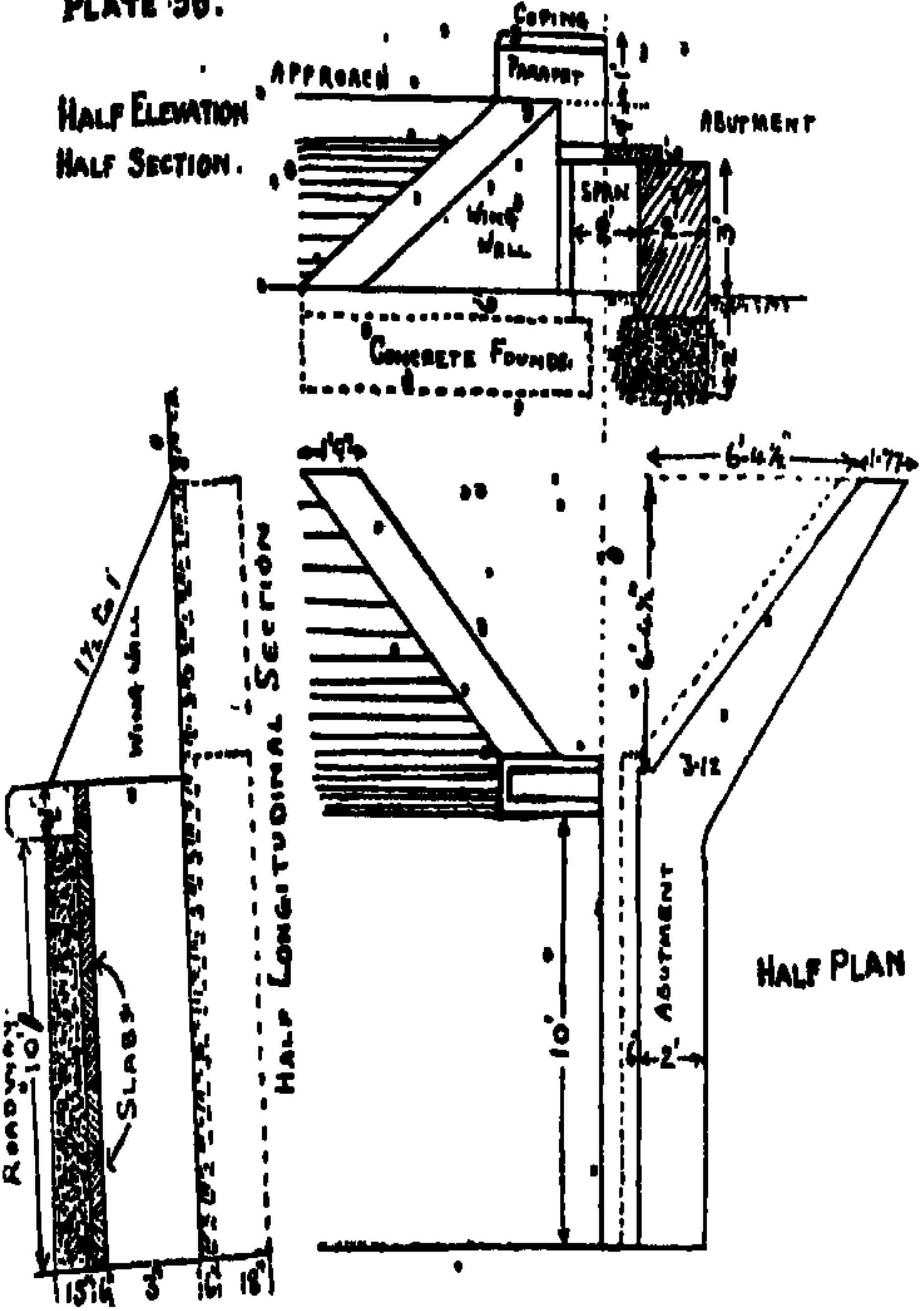
Pipe Culvert



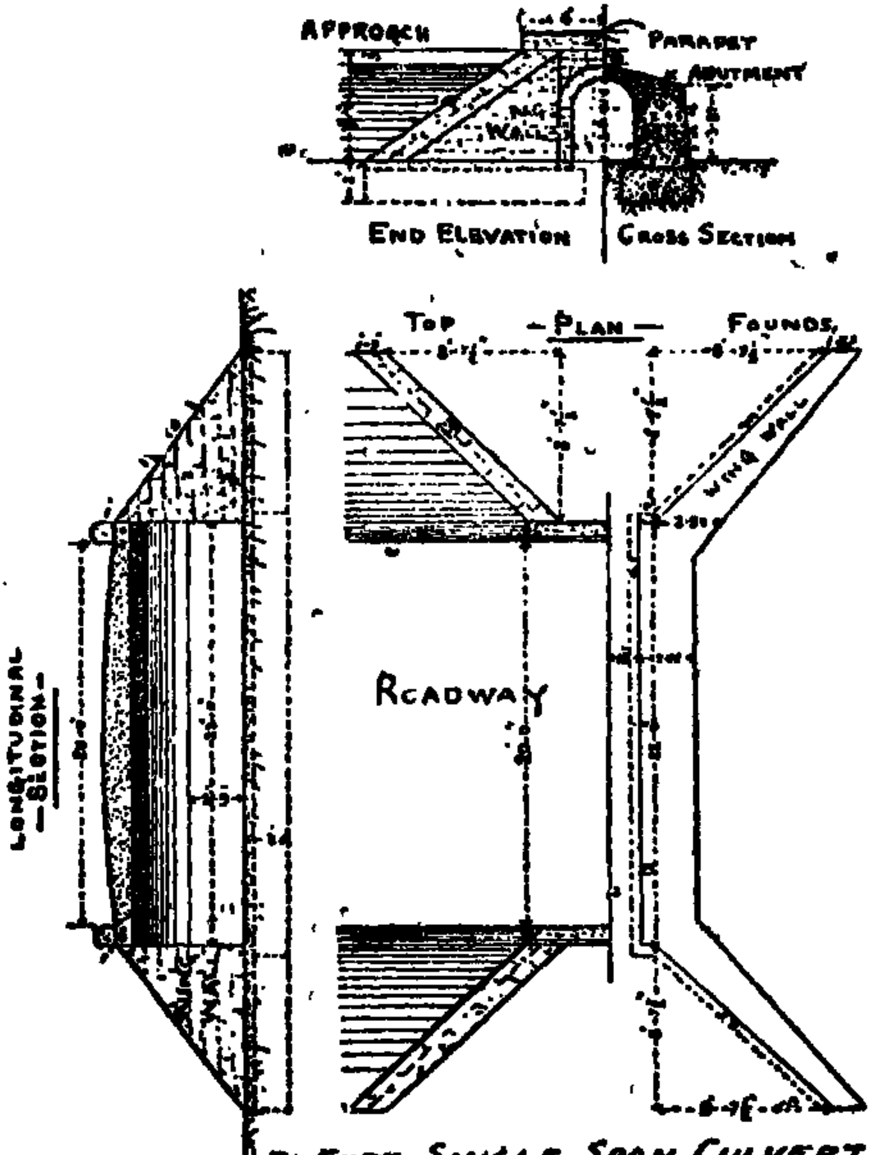
Concrete Culvert

Plate. 55.

PLATE 56.


HALF ELEVATION
HALF SECTION.
APPROACH
COPING
PARAPET
4
ABUTMENT
WING WALL
SPAN
8
2
10
CONCRETE FOUNDN.
2
HALF LONGITUDINAL SECTION
1½ to 1
WING WALL
ROADWAY 10'
SLABS
15"
6
3'
6
18"
6'-4½"
1'-7½
6'-4½
3-12
10'
ABUTMENT
2'
HALF PLAN

(e) PLATE..57.



3· FEET SINGLE SPAN CULVERT
SEMICIRCULAR ARCH

The "piers" or intermediate walls may have a thickness of one-six the span provided this thickness is not less than 1½'. The "floor" may be from 1 to 1½' thick and the "retaining" or "drop walls" 3 to 5' deep below the floor level, depending on the nature of the soil. The "wing walls" built at the end of the abutments may have an outward and downward slope corresponding to that of the embankment or may be at right angles to the abutments. In laying out a road with many culverts, select the culvert site first, and lay out its centre line before fixing the direction of the "approaches". The approaches should be in continuation of the line of the culvert or bridge for at least 60' on either bank to prevent accidents from vehicles upsetting. Where flat stones are procurable good road culverts up to 4' span can be built "dry", *i.e.*, without mortar of any sort, by "corbelling". (*See* Plate 55*a*.) This method is often used on hill roads in India.

Pipe Culverts may be constructed either of glazed sewer pipe or of iron water pipe. The former is more economical for culverts up to 30" diameter, provided it is placed on a good foundation and sufficiently covered not to be subjected to shock from traffic. The iron pipe culvert is stronger, and would be preferable where a firm foundation is not easily obtainable, or where a sufficient covering cannot be had for the vitrified pipe, as it is not so easily broken by a slight settlement or by shock. Iron pipes are however expensive and not economical for ordinary use. (*See* Plate 55*b*.) In laying pipe culverts they should be placed on a solid bed and the earth well tamped about them. The pipe should be firmly and uniformly supported from below, in order that the culvert may not be broken by settlement. The joints in the pipes should be made watertight, especially where the culvert is likely to flow full or under pressure. Any water escaping through the joints tends to cause a wash beneath the pipe and to undermine the culvert. The top of the culvert pipe should be at least 2' below the road surface to avoid crushing. The ends of the pipe culverts should be set in masonry walls to give protection against washing of the face of the embankment and to hold the ends firmly in place, as well as to prevent the entrance of water into the earth on the outside of the pipes.

Concrete Culverts may be used where a larger waterway is required than is provided by pipes. They are in most cases economical and durable if properly constructed with good materials. They may be built with arched or flat tops. For small spans the rectangular box form is usually the most economical. Plate 55*c* shows the section of a concrete culvert in which the sides, bottom and top are reinforced with steel rods. These rods take the tension due to bending under the loads which come upon it. Concrete resists the compressive stresses, but offers practically no resistance to tension. The introduction of the steel rods therefore make it possible to construct the walls and top of the culvert much lighter than they could otherwise be. Structures of this kind need careful designing and construction, to secure good results. The steel should consist of small rods bedded in the concrete and placed with their centres about 2" from the inner surface of the concrete. The area of steel required in the top of such a culvert is usually about one per cent. of the area of the concrete above it. Like pipe culverts the concrete needs protection from shocks and 18" of earth covering should be given for this purpose. The ends of the culvert must be protected by walls which should extend at least 2' below the bottom of the culvert. The thickness of the top and sides depends upon the load and the character of the concrete. They should carry safely a heavy road roller. The concrete should be made of the best grade of Portland cement mixed with good quality sand and gravel and broken stone, the proportions being :—

1 cement, 2 sand, 4 broken stone for the top.
1 „ 2½ „ 5 „ „ for the sides and bottom.

Great care is necessary in the selection of good materials. The broken stone should be good hard material, not too uniform in size, varying from about ¾" to 1½". Sand should be coarse, the grains clean and hard, but not uniform in size. The cement should comply with the specifications for Portland cement as laid down by the British Standard Committee.

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